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THE ECONOMIC IMPACT OF PROPOSED REGULATION R81-25: PROHIBITION OF CHLORINATED SOLVENTS IN SANITARY LANDFILLS

Document No. 83/08

Illinois Department of
Energy and Natural Resources

James R. Thompson, Governor
Michael B. Witte, Director

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THE ECONOMIC IMPACT OF PROPOSED REGULATION R81-25: PROHIBITION OF CHLORINATED SOLVENTS IN SANITARY LANDFILLS

By

Dames & Moore

James R. Thompson, Governor
State of Illinois

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NOTE

This report has been reviewed by the Department of Energy and Natural Resources and approved for publication. Views expressed are those of the contractor and do not necessarily reflect the position of DENR.

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CLARIFICATION AND ADDENDUM TO ENR DOCUMENT NO. 83/08

The Economic Impact of Proposed
Regulation R81-25:

Prohibition of Chlorinated Solvents
in Sanitary Landfills

by Dames & Moore

The quantities of chlorinated solvents cited in this report as 124,000 gallons for 1982 and 410,000 gallons for 1980 and corresponding interpretation of these quantities, in terms of costs and benefits, should be regarded as a range within which the actual quantities are expected to occur rather than estimated absolute quantities for the respective years.

Page 19, Figure 1 is rather confusing.

It should be noted that if the quantity of total hazardous wastes and chlorinated solvents are bar charted using the same scale for visual comparison purposes, bars representing chlorinated solvents will be hardly recognizable.

The following corrections should be noted:

1. Page 21: (Fig. 2) Landfill #4 should be Davis Junction/BFI
2. Page 24: (Table 1) Most of the chemical formulas are incorrect and should be read as noted on attachment.
3. Page 51: The disposal site is Joliet/ESL.
4. Page 68: Reference #67 - the name is NECHVATAL.

DEPARTMENT OF ENERGY AND NATURAL RESOURCES

ECONOMIC TECHNICAL ADVISORY COMMITTEE

Opinion

The Economic Technical Advisory Committee (ETAC) has reviewed and approved a study entitled: The Economic Impact of Proposed Regulation R81-25: Prohibition of Chlorinated Solvents in Sanitary Landfills. The Committee has concluded that this study meets the provisions of Public Act 80-1218.

Proposed regulation R81-25 was filed by Citizens For A Better Environment (hereinafter CBE) to ban the landfilling of chlorinated solvents in Illinois. As filed, the proposed rulemaking is based on the following conclusions cited by CBE:

1. Chlorinated solvents entering the environment are a hazard to human health;
2. Landfilling of such material may lead to their release into the environment;
3. Alternatives to landfill exist;
4. The alternatives present a lesser hazard to the environment than landfilling.[1]

As noted in this report, the disposal of chlorinated solvents is authorized at only six landfills in Illinois.[2] These landfills have been issued permits to receive hazardous wastes by the Illinois Environmental Protection Agency (hereinafter IEPA).

The consultants derived cost estimates of implementing the proposed regulation based on current landfill disposal costs, an estimate of the quantities of waste that would require disposal, and the examination of feasible alternatives to landfill disposal of chlorinated solvents.

There are two groups that will bear the costs of the proposed regulation:

the generators of chlorinated solvents for landfilling disposal and the owners and operators of landfills receiving chlorinated solvents in waste streams. The primary economic impact on the first group will be to increase their cost of disposal, an increase which can be expected to be passed through to consumers whenever possible. The consultants estimate that current cost to landfill chlorinated solvents is $90,000, which does not include transportation costs. This figure translates into a loss of revenue by landfill operators to dispose of chlorinated solvents. Of the five landfills currently receiving chlorinated solvents in Illinois, this lost revenue ranges from $500 to $58,200, based on 1982 volume data. This revenue loss is a function of the volume of chlorinated solvents received by the operator.

The State of Illinois will also lose revenues by the implementation of this proposed regulation. It is estimated that the revenue loss to the State could range between $1,240 and $4,100 per year, depending upon the volume of chlorinated solvents generated but not landfilled.

This report also includes an assessment of the benefits that could be expected should the proposed regulation be adopted. As pointed out in the report, the benefits relating to human life, health and welfare and the reduction in risk could not be quantified due to the lack of tangible evidence in the record relating to the certainty of such benefits. Nevertheless, potential benefits would accrue to those persons residing near, or working at landfills, to owners and operators of firms engaged in the transportation of hazardous wastes. Also, there is the possibility that a reduction in risk would accrue to the populations residing near landfills currently accepting chlorinated solvents.

It should be noted that the magnitude of potential benefits would also include the reduced risk of possible contamination of sources of potable water. Wastes such as chlorinated solvents may enter such water supplies either through leaching into ground water or by runoff into surface waters. Thus, reduction in the potential for ground water contamination could provide significant benefits through the avoidance of costs to cleanup a contaminated auquifier. The consultant estimates that the cost associated with emergency containment to be $3.2 million per site. However, it should be acknowledged that this is a speculative benefit at best.

Finally, the State may experience a reduction in monitoring costs ranging between $46,760 and $43,900; these figures depending on the volume of waste generated. No significant secondary benefits are anticipated to materialize as a result of adoption or denial of proposed regulation R81-25.

FOOTNOTES

[1] Proposed Regulation R81-25.

[2] Based on available information at the time this study was being prepared.

CONTENTS

EXECUTIVE SUMMARY. vi

1.0 INTRODUCTION 1

1.1 PROPOSED REGULATION 1

1.2 OVERVIEW OF LAND DISPOSAL PRACTICES AND ALTERNATIVES. . . 2

1.3 BENEFITS OF REGULATION. 4

1.4 COSTS OF REGULATION 5

1.5 ALTERNATIVES TO LAND DISPOSAL 6

1.5.1 Solvent Reclaiming/Reuse 7

1.5.2 Incineration 8

1.5.3 Wet Oxidation Process. 13

1.5.4 Supercritical Water Reforming. 14

1.5.5 Deep Well Injection. 15

1.5.6 Solidification/Stabilization 16

1.5.7 Other Technologies 16

2.0 CURRENT PRACTICES AND EXISTING ALTERNATIVES FOR THE DISPOSAL OF CHLORINATED SOLVENTS IN ILLINOIS. 18

2.1 CURRENT LAND DISPOSAL PRACTICES 18

2.1.1 Quantities 18

2.1.2 Geographic Distribution of Generators and Disposal Sites 18

2.1.3 Physical Characteristics of Waste Chlorinated Solvents 20

2.1.4 Toxicology, Migration Potential and Persistence of Chlorinated Solvents 22

2.2 CONSIDERATIONS FOR LAND DISPOSAL. 28

2.2.1 Segregation of Waste Chlorinated Solvents 30

2.2.2 Leachate Migration/Liner Interception 30

2.2.3 Cost of Land Disposal 36

2.2.4 Environmental Consequences of Land Disposal . . . 36

CONTENTS (continued)

2.3 EXISTING ALTERNATIVES TO LAND DISPOSAL IN ILLINOIS. . . . 37
  2.3.1 Solvent Reclamation/Recycling. 37
  2.3.2 Incineration 40
  2.3.3 Other Facilities 41
  2.3.4 Cost of Alternatives 42
  2.3.5 Environmental Consequences of Alternatives 42
3.0 BENEFITS 44
3.1 IDENTIFICATION OF IMPACTED POPULATION 44
3.2 ESTIMATED NATURE AND MAGNITUDE OF BENEFITS. 45
  3.2.1 Nature of the Benefits 45
  3.2.2 Estimated Magnitude of Benefits. 46
3.3 SECONDARY BENEFITS. 50
4.0 COSTS. 51
4.1 IDENTIFICATION OF THE COST-IMPACTED POPULATION. 51
4.2 NATURE AND MAGNITUDE OF COSTS 52
  4.2.1 Nature of Costs. 52
  4.2.2 Magnitude of Costs 53
4.3 SECONDARY ECONOMIC BENEFITS 57
5.0 COMPARISON OF BENEFITS AND COSTS 59
5.1 SUMMARY OF BENEFITS AND COSTS 59
5.2 DISTRIBUTIONAL EFFECTS. 61
6.0 BIBLIOGRAPHY 63

FIGURES

Number   Page

1 Quantities of Hazardous Wastes Disposed in Lanfills in Illinois 19

2 Locations of Generators and Disposers of Chlorinated Solvents. 21

TABLES

Number   Page

1 Physical Properties of Chlorinated Solvents 24

2 Toxicological Data For Chlorinated Solvents 25

3 Incompatible Waste Groups 31

4 Comparison Of Landfilling To Alternatives 38

5 Landfill Operators and Estimated Revenue Losses 55

6 Estimated Costs of Alternatives 58

EXECUTIVE SUMMARY

A regulation to ban the landfilling of chlorinated solvents in Illinois has been proposed by Citizens for a Better Environment. The proposed rulemaking has been identified as R81-25, and is based on the following conclusions of the petitioner:

1. Chlorinated solvents entering the environment are a hazard to human health;
2. Landfilling of such material may lead to their release into the environment;
3. Alternatives to landfilling exist; and
4. The alternatives present a lesser hazard to the environment than landfilling.

The quantity of waste chlorinated solvents in Illinois disposed in landfills has decreased from approximately 410,000 gallons in 1980 to approximately 124,000 in 1982. The quantity of all hazardous wastes disposed in Illinois landfills has decreased by nearly 70 percent over the same time period. A 1982 ban on the landfilling of all free, hazardous liquids and the economic recession have contributed to this decrease.

The disposal of chlorinated solvents is authorized at only six landfills in Illinois. These landfills have been issued permits to receive hazardous wastes by the Illinois EPA. Only five, however, have received chlorinated solvents during 1982, and all are located within 200 miles of Chicago. Chlorinated solvent wastes make up a very small portion of the wastes disposed of at any landfill.

Alternatives to the land disposal of chlorinated solvents include the following methods:

- incineration;
- solvent reclamation;
- wet oxidation;
- coincineration;
- supercritical water reforming;
- deep well injection; and
- solidification/encapsulation.

Of these alternatives, only incineration and solvent reclamation facilities are operational and permitted to receive chlorinated solvents in Illinois. There is abundant excess capacity in Illinois to accomodate the quantities of chlorinated solvents currently being landfilled using either method.

If the proposed ban on landfilling chlorinated solvents is adopted, the generators of these materials would reclaim a relatively small percentage (<20 percent) and incinerate the remainder. This is because of the requirement for a fairly high-quality solvent stream in order for reclamation to be cost effective or even possible. In addition, the reclamation process produces a chlorinated solvent sludge as a waste product, and this sludge itself must be incinerated.

The benefits of the adoption of the proposed rulemaking include the following:

- A decrease in the exposure of the population residing near landfills currently accepting chlorinated solvents for disposal to those wastes and a concomitant reduction in the risk that their health may be impaired as a result of these wastes entering the environment.

- An increase in the revenues of firms providing solvent reclamation, incineration, and transportation services.

- A decrease in the administrative expense to the State of Illinois in the enforcement and monitoring of hazardous waste regulations.

- Reduced potential for potable water supply contamination resulting from the leaching and migration of wastes from landfills.

- A decrease in the liability incurred by both generators of the wastes and landfill operators by reducing the potential for environmental degradation from these wastes.
- An increase in the potential serviceable life of the landfills currently receiving these wastes.

The primary costs of the proposed rulemaking will be the additional costs of disposal of chlorinated solvents, and these costs will be borne by the generators of such wastes. Based on the estimated range of volume of annual waste solvent generated in Illinois, the incremental costs of alternatives to landfilling range as follows:

$150,000 to $1,150,000

or

$1.21/gallon to $2.80/gallon.

Given the small magnitude of primary costs, no significant secondary costs are perceived as likely due to the proposed rulemaking. Similarly, no significant secondary benefits are foreseen, either. Finally, no significant effect is expected on such things as the availability of goods and services, agriculture, or local government.

1.0 INTRODUCTION

1.1 PROPOSED REGULATION

Citizens for a Better Environment, a nonprofit Illinois corporation composed of approximately 3,500 members has proposed a regulation to ban the landfilling of chlorinated solvents in sanitary landfills in Illinois. This proposed rulemaking is identified as R81-25. Chlorinated solvents refer to those wastes identified by the Environmental Protection Agency's Hazardous Waste Numbers F001 and F002 which are defined as:

> F001 - The following spent halogenated solvents used in degreasing: tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons and sludges from the recovery of these solvents in degreasing operations.
>
> F002 - The following spent halogenated solvents: tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, orthodichlorobenzene, and trichlorofluoro-methane; and the still bottoms from the recovery of these solvents.

Sanitary landfills include all landfills permitted by the Illinois Environmental Protection Agency to receive both hazardous and nonhazardous wastes in Illinois. The proposed regulation would therefore ban the land disposal of the above halogenated wastes in the state of Illinois (Ref 30).

The regulation was proposed based on the petitioner's conclusions that; (1) chlorinated solvents would be hazardous to human health if allowed to enter the environment; (2) the land burial of the solvents may lead to the release of these substances to the environment; (3) specific technology exists to recycle, recover or treat these wastes; and (4) these alternate technologies will present a lesser hazard to the environment than land burial of the original wastes (Ref 47).

1.2 OVERVIEW OF LAND DISPOSAL PRACTICES AND ALTERNATIVES

Current practices of land disposal which include the design and operations of landfills are presented in Chapter 2. The exposure of improper disposal practices such as Love Canal and Valley of the Drums has made the public aware of the consequences of the contamination of ground water, soil and air by the hazardous constituents of disposed wastes.

Some chlorinated solvents have been found to be carcinogens by the Carcinogen Assessment Group of the United States Environmental Protection Agency (USEPA) and most are listed as priority pollutants under Secion 307 of the Clean Water Act. Toxicology data are presented in Chapter 2. Most of these data pertain to the effects on humans exposed to high concentrations or to the effects on animals, rather than the effects of exposure to lower concentrations found in contaminated ground waters and soils.

Regulations under the Resource Conservation and Recovery Act were promulgated in 1980 to minimize the potential for interaction and release of hazardous constituents into the environment. Requirements specific to landfills concern the segregation of wastes in order to minimize interactions and the use of a suitable barrier such as a liner to intercept and contain landfill leachate. Studies of long-term exposure of liners and/or solidification and encapsulation materials indicate that these are not failure-proof and that they tend to deteriorate after exposure to organic compounds such as the chlorinated hydrocarbons that chlorinated solvents are made of. There can be no guarantee that chlorinated solvents will not eventually permeate through a landfill, the liner and the underlying soils and ground water.

Alternatives to land disposal of chlorinated solvents that have been identified in current literature are presented in Section 1.5. These alternatives include solvent reclamation, incineration, coincineration, wet oxidation, supercritical water reforming, deep well injection and the solidification or encapsulation of wastes prior to land disposal.

The only alternatives currently operational and permitted to receive chlorinated solvents in Illinois are solvent reclamation and incineration facilities. There are three incineration facilities currently permitted to receive chlorinated solvents. One of these is reported to have permitting and operational problems; however, the remaining two facilities have ample capacity to handle the estimated 124,000 gallons of chlorinated solvents currently being landfilled in Illinois on an annual basis. The estimated available incinerator capacity for chlorinated solvents in Illinois is over 3 million gallons per year; 63,500 gallons at one facility, and the remainder at an SCA incinerator.

Discussions with solvent reclaimers in Illinois have revealed that they have more than enough capacity to handle the estimated 124,000 gallons of waste solvents as long as they are in liquid form. Results of the Dames & Moore telephone survey indicate that there is a remaining capacity of at least 2-1/2 million gallons per year for chlorinated solvent reclamation. However, only a small fraction of the chlorinated solvents would be amenable to recovery and the relatively large quantity of sludge produced (55 percent of the original waste) requires that an ultimate destruction/disposal option remain in operation. In addition, air emissions of chlorinated compounds result from the distillation, storage and transfer of waste chlorinated solvents at reclamation facilities. The recycling of waste solvents results in a waste volume reduction of about 45 percent.

Incineration drastically reduces the potential for emissions of chlorinated solvents to the environment. Only incinerators which operate at a minimum of 99.99 percent efficiency are allowed to dispose of chlorinated solvents in Illinois. This normally requires an afterburner and scrubber equipment to control air emissions. Waste products include a small volume of ash or slag containing heavy metals, a wastewater containing salts and a neutralized scrubber solution. Only the ash contains the hazardous heavy metal constituents which must be landfilled in a facility permitted to receive hazardous wastes.

1.3 BENEFITS OF REGULATION

The proposed regulation to ban the landfilling of chlorinated solvents in Illinois by the Citizens for a Better Environment was based on perceived environmental and health benefits rather than any resulting economic benefits.

Based on the results of studies of the permeabilities of clay and synthetic liners in landfills and of the currently available materials for solidifcation and encapsulation, it appears that there are no reliable methods for the secure land disposal of chlorinated solvents. The adsorption of liquids onto solids or sorbents prior to landfilling does not prevent the desorption of the liquids and leachate formation once in place. The use of alternatives currently available in Illinois such as incineration and solvent reclamation would reduce the quantity and potential for release of chlorinated solvents into the environment. (These alternatives are discussed in Section 1.5). Thus, the proposed regulation would likely benefit the people of

Illinois in regard to health and the environment. It is difficult to quantify the extent of this benefit, however.

The proposed regulations would benefit currently operating solvent reclaimers and incineration facilities that are permitted to receive chlorinated solvents due to the increase in wastes received and the higher charges associated with the treatment and destruction of these waste compounds. The regulation would also encourage the development of new treatment processes.

The ban on land disposal of chlorinated solvents would lessen the probability of release of toxic substances and resulting litigation of landfills currently disposing these wastes, thereby reducing insurance costs to generators and landfill owners and the costs of meeting the stricter standards to be enforced in the future on the design, construction and operation of landfills.

1.4 COSTS OF REGULATION

Generators of chlorinated solvents would be most affected by this proposed regulation, with landfill owners also being affected but to a lesser degree. The quantity of chlorinated solvents currently being landfilled on an annual basis in Illinois is estimated to be 124,000 gallons. This represents about 0.4 percent of the total quantity of hazardous wastes currently being landfilled; an insignificant portion of the potential income to landfill owners. Generators will therefore bear the increased cost of disposal. This cost will be somewhat offset by a decrease in the probability of litigation and possible clean-up costs associated with a future leaking landfill cell and by whatever savings will be realized on the relatively small fraction of recyclable solvents being reclaimed. The distribution of generators, landfills, solvent reclaimers, and incinerators are similar so that transportation costs would not be greatly affected.

1.5 ALTERNATIVES TO LAND DISPOSAL

Several possible alternatives to landfilling have been identified in the literature. The alternatives differ significantly from each other in efficiences of treatment, waste streams produced, stages of development from planning to operation, and in costs. Alternatives receiving the most publicity include solvent reclamation, incineration, wet oxidation, coincineration, deep well injection, and solidification techniques in which wastes are solidified or encapsulated to prevent leachate formation and release. A close review of these processes shows that wet oxidation will only partially destroy chlorinated organics, coincineration of fuel with chlorinated organics is basically in the experimental stage, solidified wastes are subject to eventual deterioration by organics present in the waste and other technologies have not yet been proven in full scale demonstrations. Solvent reclamation processes reclaim approximately half of the waste chlorinated solvent received and generate the remaining half as chlorinated waste sludges. Deep well injection may be a viable alternative, but construction materials must be compatible with the solvent. Incineration appears to be the only full-scale operating destruction technique currently available for chlorinated solvents. The alternatives are described and discussed below.

1.5.1 Solvent Reclaiming/Reuse

The chlorinated solvents usually reclaimed by industry include carbon tetrachloride, fluorocarbons, methylene chloride, perchloroethylene (tetrachloroethylene), trichloroethylene and 1,1,1 trichlorethane. Cleaning operations, which include dry cleaning and metal degreasing, and private contractors operate the vast majority of solvent reclaiming facilities. Private contractors vary considerably from those blending waste solvents with raw materials to produce specialty chemicals to those who buy waste solvents from a set clientele and reclaim and sell back the same solvents to the same customer for a fraction of the cost of a virgin solvent. The economic viability of solvent reclaiming depends on market conditions, demand for a given solvent and the degree of contamination of a given solvent. The cost of recycling varies from the least expensive case of a relatively clean single solvent to the most expensive case of a high solids- and metals-containing solvent mixture which under normal operating conditions would not be recycled (Ref 83).

The reclaiming process for liquid solvents may be broken down into the three separate steps; mechanical separation, distillation and purification. Some of these steps may be omitted depending on the type and degree of contamination of the waste solvent. The process is the same for halogenated and non-halogenated solvents. Mechanical separation involves decanting, filtering, draining, settling or the use of a centrifuge to remove solids such as metal fines (Ref 83).

Different fractions of the waste solvent are separated from each other on the basis of boiling point differences, and dissolved impurities are removed in the distillation process. The distillation process varies among solvent reclaimers and operating conditions depend upon the desired purity of the finished product as well as the boiling points of the waste solvent mixture. After distillation, any remaining water is removed from the solvent by decanting if the solvent is immiscible in water, or by a salting process in which water is absorbed into a calcium chloride bed as the solvent passes through. Any additives such as buffers are then added, if necessary, as the final step (Ref 83).

Approximately 55 percent of the waste solvent will become a waste sludge from the mechanical separation or distillation process and cannot be further reclaimed. Solvent reclaiming can therefore be thought of as a treatment and waste volume reduction process, not a destruction technique. The customer of a solvent reclaiming operation can expect to save 20-40 percent of the cost of a virgin solvent but is limited by the degree of contamination and the type of waste solvent being generated (Ref 24, 54, 83).

1.5.2 Incineration

The USEPA has estimated that out of the 850 operating incinerators in the United States, only 43 meet the following RCRA operating requirements for the treatment of hazardous wastes:

- o 99.99 percent destruction and removal efficiency for each principal organic hazardous compound (POHC) (these include the chlorinated organics in chlorinated solvents);
- o 99 percent removal of hydrogen chloride from the exhaust gas for wastes containing more than 0.5 percent organically bound chlorine (such as chlorinated solvents); and
- o air emission limit no more than 180 milligrams particulate matter per dry standard cubic meter of exhaust gas.

Only a fraction of the incinerators that meet these standards are commercial, off-site units (Ref 68).

Incinerator systems vary in design type and in capability to handle different waste streams depending on the design of the incinerator, the presence of an afterburner and the presence of extensive pollution control equipment. The RCRA operating requirements listed above may limit the amount of halogenated compounds, ash content, chlorine content and metal content acceptable to a given unit. Wastes high in these contaminants may be blended with other "cleaner" wastes to meet these operating conditions in some systems. Inorganic salts, nitrogenous compounds, sulfur and phosphorous groups which may cause wear and corrosion or scaling can be blended to mitigate wear and tear on incinerator components. Wastes high in water and having a low energy content may also require blending with other wastes or with auxiliary fuel in order to burn at a high enough temperature such that toxic compounds can be destroyed (Ref 97, 99).

Incinerators achieve destruction of toxic compounds by thermal decomposition at high temperatures. Thermal decomposition is achieved primarily by oxidation or combustion, and is aided by pyrolysis or the energy supplied by heat alone without the presence of oxygen. Pyrolysis breaks down some toxic compounds into non-hazardous compounds and also rearranges compounds into forms which are more easily oxidized. The performance of an incinerator in destroying hazardous constituents depends upon the maintenance of a consistently high temperature for proper oxidation, complete mixing of fuel and air, an adequate retention time and a proper oxygen supply. High temperatures and long retention times are required to destroy chlorinated solvents. A great deal of attention and planning is required in order to properly blend halogenated solvents with other wastes or with auxilary fuel to achieve a waste blend that is sufficient in energy value and low enough in impurities to meet the operating requirements of the specific incinerator (Ref 68, 74, 99).

Several types of incinerators are available. These include:

- o rotary kiln;
- o liquid injection;
- o other
  - fluidized bed;
  - multiple hearth;
  - starved air combustion/pyrolysis; and
  - coincinerators.

Liquid injection incinerators account for more than 80 percent of the operating incinerators in the United States today. Approximately 9 percent of operating incinerators are rotary kiln, with the remaining 11 percent of incinerators being fludized bed, multiple hearth or pyrolysis types. Coincineration is still in the experimental stage. These are described in more detail in the following paragraphs (Ref 68).

Rotary Kiln

Rotary kiln incinerators are capable of treating liquids, solids and sludges in bulk or in drums. The versatility of the rotary kiln is the reason that it is most frequently used for commercial off-site units. Operating temperatures between 800 to 1600°C and residence times between seconds and hours are achievable (Ref 48, 99).

When followed by an afterburner and air pollution control equipment, rotary kilns can handle all types of halogenated compounds including chlorinated solvents and organics containing phosphorus, sulfur and silicones. Afterburners are normally liquid injection incinerators and are used to provide addtional combustion of unburned hydrocarbons at an elevated temperature. Scrubbers are used to remove particulates and acid gases such as sulfuric and hydrochloric acid created from the oxidation of sulfur compounds or chlorinated hydrocarbons in the waste (Ref 14, 68).

Liquid Injection

Liquid injection incinerators require pumpable and atomizable feeds such as liquids and some slurries. The vertically designed unit allows for the destruction of wastes high in inorganic salts and ash, while the horizontal system is more limited. Liquid injection systems operate at combustion temperatures between 650 to 1600°C and can vary in residence times from a fraction of a second to two seconds. When accompanied by pollution control equipment, liquid incinerators are capable of receiving many chlorinated solvents (Ref 68, 74).

Other Systems

Fluidized bed incineration is applicable to most types of organic wastes and accepts solids, liquids and gases. It is capable of handling almost any waste that the rotary kiln can, however, solid wastes must be pretreated prior to injection. Operating temperatures can vary from 450 to 1000°C and residence time can vary from a second to longer periods for solids combustion (Ref 48, 74).

Multiple hearth types are mainly used for sewage sludge, solids and sludges. They operate between 315 to 1000°C and from 0.25 to 1.5 hours. They are capable of handling the same hazardous wastes as rotary kilns which allow for pretreatment of solids. A secondary combustion chamber is probably necessary and different operating temperatures might be necessary for the treatment of hazardous wastes. Starved air combustion/pyrolysis units cannot treat chlorinated compounds (Ref 48, 74).

Coincineration

Coincineration is the substitution of wastes for fuel in the generation of energy and is therefore currently exempt from RCRA regulations due to its status as a reclamation/re-use/recycling process. The major candidates for coincineration are waste heat boilers and cement kilns, the latter having the greatest potential for chlorinated solvents. Coincineration of hazardous wastes on a large scale is still in experimental stages.

Several tests have been performed on the substitution of chlorinated organics and polychlorinated biphenyls (PCB's) for fuel in wet kilns for cement production and have confirmed that essentially complete destruction of waste feed can be accomplished. The total chlorine content of the fuel must be controlled to avoid corrosion problems, deterioration of clinker quality and adequate waste destruction. There is sufficient wet kiln capacity in the United States to destroy nearly four times the annual quantity of chlorinated hazardous waste produced.

Tests, mainly with polychlorinated biphenyls, have also been conducted in high temperature industrial boilers; however, some of the boilers did not provide sufficiently high temperatures and sufficiently long residence times for the complete destruction of PCB's. The combustion of halogenated waste may also increase corrosion of heat exchanger surfaces (Ref 68).

Incineration in the correct system appears to be a safe and demonstrated method for the 99.99%+ destruction of chlorinated solvents. Afterburners and air emission control equipment are normally required for complete removal of chlorinated hydrocarbons and resulting combustion products. Waste streams from incineration are the quench water which is generally acidic from the combustion of chlorinated hydrocarbons scrubber effluent containing high concentrations of total dissolved solids, and bottom ash or slag containing inerts and fly ash entrained in exhaust gases. Scrubber effluents and quench water are often combined, pretreated and discharged to a municipal treatment plant or are treated and discharged to a surface water. They should not contain hazardous constituents. Bottom ash will contain less than 3 percent trace compounds including heavy metals and should be disposed in hazardous waste landfills (Ref 9).

Typical costs of incineration found in the literature fall in the range of $118 to $237 per 55 gallon drum for highly toxic and solid wastes, and from $23 to $600 for the entire range of chemicals that may be incinerated (Ref 5, 98).

1.5.3 Wet Oxidation Proceses

Wet oxidation processes are now used extensively in the treatment of municipal wastewaters and are amenable to receiving aqueous wastes and organic liquids, sludges and solids. Two American companies have developed wet oxidation processes for the treatment of hazardous wastes including chlorinated solvents. IT Corporation is marketing a catalyzed wet oxidation process and Zimpo also has a wet air oxidation process (Ref 5, 98).

Wet oxidation is the aqueous phase oxidation of dissolved or suspended organic materials at an elevated temperature and pressure. Temperatures are much lower than those found in incineration. Wet oxidation supposedly does not require extensive particulate and other emission control devices and does not require supplementary fuel after start-up (Ref 5).

IT Corporation's catalyzed wet oxidation process has not been subject to a full-scale demonstration. Due to the presence of a catalyst (bromide, nitrate and manganese ions in an acidic solution), it operates at a lower temperature of 165-200°C and a pressure which is lower than usually found in wet oxidation systems. Residence times can vary between 30 minutes and two hours. Tests run on the halogenated compounds of ethylene bromide, hexachlorobutadiene and trichloropropane showed that the halogenated species were only partially oxidized even when temperatures were raised to 200-250°C and at a 2-hour retention time (Ref 60).

Zimpro's wet air oxidation process was originally only used for municipal waste-sludge treatment and is now being applied to hazardous waste streams containing 10 percent or less organics. It operates at temperatures from 230-275°C while air is bubbled through the waste stream. Incomplete oxidation of some wastes has been observed and it is difficult to achieve 99.99 percent destruction of organics (Ref 5).

Wet oxidation currently does not appear to be a viable process for the destruction of chlorinated solvents. Costs of destroying organics are estimated to be $0.15 to $0.30 per pound of organic for the catalyzed system. This corresponds to a cost of $0.70 to $1.40/gallon ($38.50 - $77.00 per drum) for the partial destruction of chlorinated solvents (Ref 60).

1.5.4 Supercritical Water Reforming

A new thermal process has been developed by Modar, Inc. called supercritical water reforming. The process can accept liquid, sludges and solids which can be slurried with water. Waste must contain a minimum of 5 percent of organics. Modar is in the process of building a portable 1,500 gallon per day demonstration unit and is arranging to sell both large and small supercritical water oxidation systems worldwide (Ref 5, 98).

The process depends upon the fact that oxygen and many refractory organics are highly soluble in water above a critical condition of 374°C and 1760 atm. The Modar process operates at a temperature of 550°C and a high pressure (2040 atm) with a residence time of less than one minute. At these operating conditions the carbon and hydrogen in wastes are rapidly oxidized while halogens, phosphorus, sulfur and the metals in the feed combine to form solid salts which can then be filtered out. Bench scale tests have achieved greater than 99.99+ percent efficiency for destroying chemical wastes containing polychlorinated biphenyls, 1,1,1-trichloroethane, trichloethylene, o-chlorotoluene, 1,2-ethylene dichloride, 1,1,2,2 tetrachloroethylene and others (Ref 15, 98).

The supercritical water reforming process has not yet been demonstrated at full-scale operation but prospects look good for doing so. Modar projects a processing cost of $10 to $30 per gallon of organics for its 50 gallon per day mobile unit and $0.10 to $2.00 per gallon ($5.50 to $16 per drum) for its 2500 to 25,000 gallon per day unit which is still in the development stage (Ref 5, 15, 98, 62).

1.5.5 Deep Well Injection

Deep well injection involves the injection of pumpable liquids or sludges into porous sandstone and limestone formations 1000 to 3000 meters below ground level. Most deep wells exist in the oil producing states with the majority located in Texas and Louisiana where they have been used for the disposal of brine, but others are located in Colorado, Illinois, Ohio and Michigan. Only a few are used for commercial disposal. A total of 20 states allow disposal by deep well injection, but some have limitations on compounds such as chlorinated hydrocarbons (Ref 43).

Proponents of deep well injection claim that it is safe and inexpensive. Sites have contained brines that have been separated from fresh water zones for millions of years by layers of impervious shale. Critics are concerned about the lack of knowledge on the ultimate fate of toxins and the potential for resulting hazards such as earthquakes, eruptions, and infiltration into potable waters and economic minerals.

The key to deep well injection involves the selection of a geologically suitable site, the proper design of the well, and the compatibility of the materials of construction with the wastes being received. Once the well is drilled the cost of operation is almost negligible, making the average cost of disposal in the range of 8 to 14 cents per gallon or $4.40 to $7.70 per 55 gallons (Ref 43, 57).

1.5.6 Solidification/Stabilization

Solidification and stabilization techniques are currently being used for only a small percentage of wastes. Existing methods can be divided into four categories; cement based, pozzolonic, thermoplastic and polymeric. Techniques greatly differ in chemicals used, resulting chemical properties and costs, but all appear to be subject to gradual deterioration by organics present in the waste. Costs vary between $5 and $500 per ton of waste or $1.65 to $165 per 55 gallons (Ref 43, 57).

1.5.7 Other Technologies

Several other processes for the treatment/destruction of hazardous wastes are in various stages of development but have not been proven on a full scale. These include a molten salt destruction (MSD) process by Rockwell International which has shown greater than 99.99 percent destruction efficiency on a variety of hazardous organic wastes including polychlorinated biphenyls, pesticides and chemical warfare agents. Anti-Pollution Systems (APS) has also developed a molten salt process, but little is known about the potential of either method to process large volumes of waste for an extended period of time (Ref 25, 98).

Other innovative technologies are also being developed. Atlantic Research Corporation has developed a process for the light activated reduction of chemicals (LARC) using ultraviolet light and hydrogen to destroy compounds such as halogenated organics. Thagard Research is developing a high temperature fluid wall (HTFW) reactor; Now Energy Inc. is marketing a fluidized bed incinerator and Franklin Research Center has developed a molten sodium process for destroying chlorinated hydrocarbons (Ref 26, 95, 98).

2.0 CURRENT PRACTICES AND EXISTING ALTERNATIVES FOR THE DISPOSAL OF CHLORINATED SOLVENTS IN ILLINOIS

2.1 CURRENT LAND DISPOSAL PRACTICES

2.1.1 Quantities

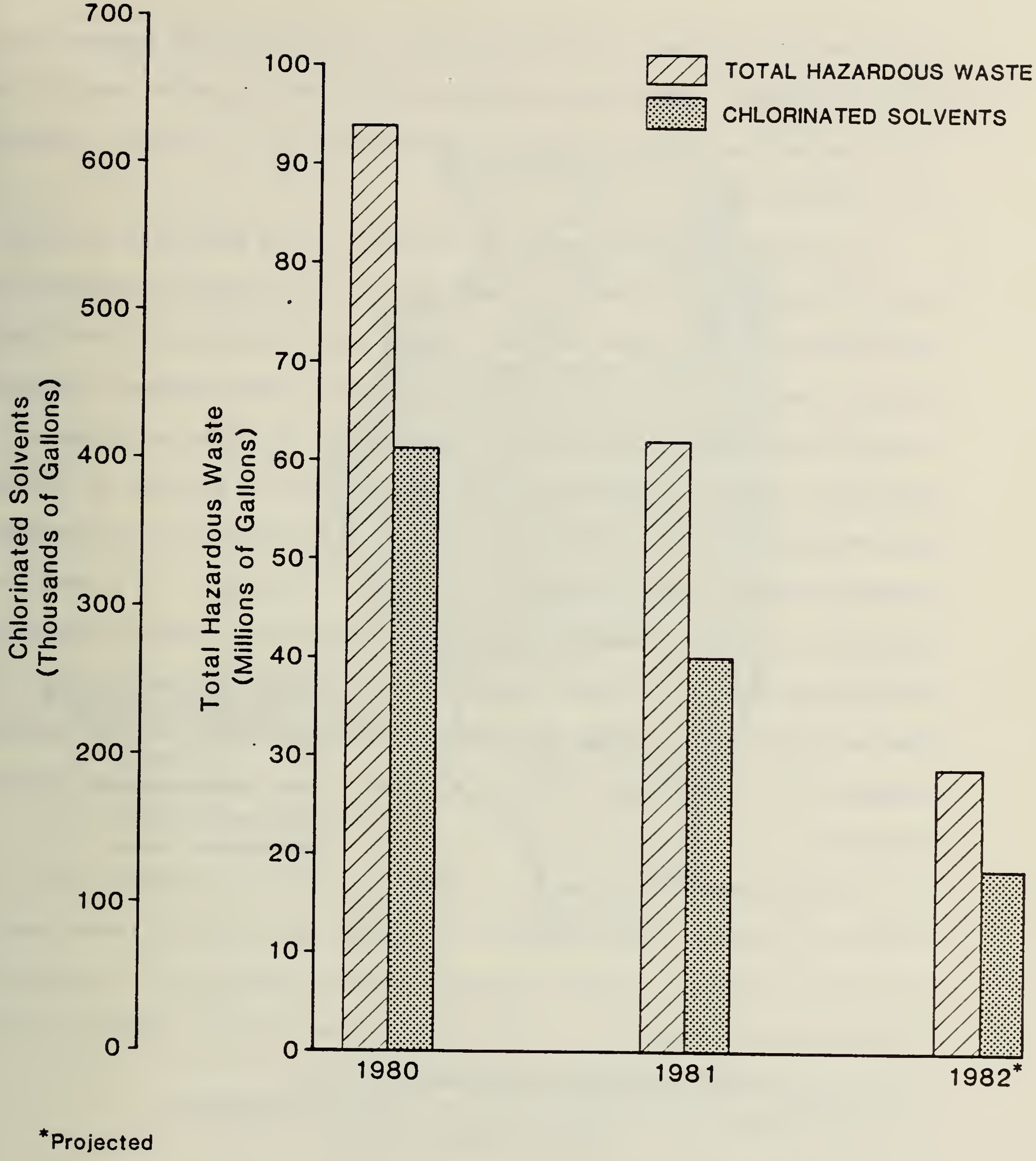
The implementation of federal and state regulations controlling hazardous waste management has affected the land disposal of chlorinated solvents in Illinois as well as the land disposal of all hazardous wastes. The quantity of hazardous waste disposed of in Illinois landfills has decreased from about 95 million gallons in 1980 to an estimated 29 million gallons in 1982 (Ref 67). A 1982 ban on the landfilling of all free, hazardous liquids in Illinois, and the economic recession have contributed to this decrease.

A review of the records on file at the Illinois Environmental Protection Agency showed that many of the wastes landfilled in Illinois were not specifically named by compound, waste type or EPA identification number (such as F001 or F002). Many of the wastes disposed were listed more generally with names such as degreasing waste, mixed solvents, solvent cleaning waste and still bottoms. Records of the listed wastes and estimates of the halogenated fraction of the other wastes show that approximately 410,000 gallons of chlorinated solvents were disposed in landfills in 1980 and approximately 124,000 gallons will be disposed in 1982 (Ref 46).

Figure 1 presents the landfilled quantities of hazardous waste and chlorinated solvents for 1980 through 1982.

2.1.2 Geographic Distribution of Generators and Disposal Sites

The locations of generators of chlorinated solvents is consistent with concentrations of industrial operations in the state. Over 73 percent of the



QUANTITIES OF HAZARDOUS WASTES
DISPOSED IN LANDFILLS IN ILLINOIS

From Reference Nos. 46 and 67

Dames & Moore

Figure 1

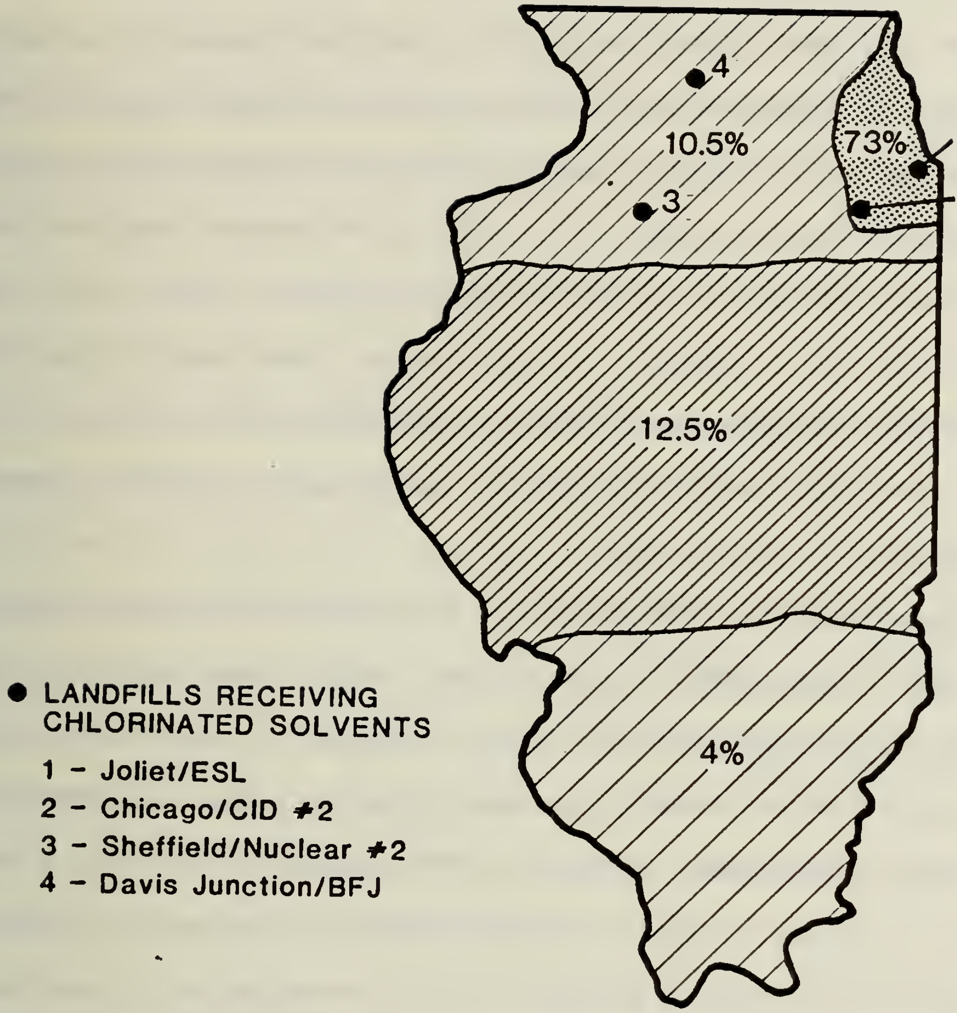
generators are located in the Chicago area, with nearly equal portions (12.5 and 10.5 percent, respectively) shared by the north and central sections and lesser percentages (four percent) in the south (Ref 92). Figure 1 presents this distribution.

Six privately owned, commercial landfills are permitted to receive hazardous wastes in Illinois. These are the only landfills authorized by the Illinois EPA to receive hazardous wastes from any source, including small quantity generators. Only four of these landfills have received chlorinated solvents during 1982. They are all located within 200 miles of Chicago. The Joliet/ESL landfill located in Elwood near Chicago is operated by Chemical Waste Management, Inc. and will receive close to 65 percent of the chlorinated solvents that will be disposed of in Illinois landfills. The Sheffield/ Nuclear #2 landfill is operated by U.S. Ecology and is located in Sheffield, the northern part of Illinois, approximately 180 miles west of Chicago. The Sheffield site will receive 16 percent of the chlorinated solvents annually disposed of in Illinois landfills. Figure 2 shows the locations of these landfills.

The Chicago/CID #2 landfill operated by Waste Management, Inc., is located in Calumet City adjacent to Chicago and receives approximately 14 percent of the chlorinated solvents annually landfilled. The remaining 5 percent are disposed of at the Davis Junction landfill operated by BFI, approximately 190 miles from Chicago (Ref 46).

2.1.3 Physical Characteristics of Waste Chlorinated Solvents

Waste chlorinated solvents disposed of in Illinois landfills can be categorized into three major groups in regard to physical state and chemical



LOCATIONS OF GENERATORS
AND DISPOSERS OF CHLORINATED SOLVENTS
From Reference No. 92

Figure 2

composition; liquid-high solvent content, liquid-aqueous solution, and sludge/ high-solids solvent content. Those in the liquid high chlorinated solvent content category consist of spent solvents which vary in solids content up to 13 percent and usually contain below 1 percent inorganic salts. Oil and grease content varies up to 9 percent and many contain lead or zinc in concentrations of 100 mg/l. The spent chlorinated solvents normally contain up to 90 percent of the original solvent. The waste aqueous solutions contain up to 7 percent solids and up to 100 mg/l of lead. These are rinse or contaminated waters. Liquids, the majority of which have high solvent content, account for about two-thirds of the landfilled chlorinated solvents in Illinois. Prior to landfilling, these liquids were mixed with sorbents or general refuse.

Solid content varies from 20 to 100 percent in the sludge-high-solids solvent category. Degreasing sludges and still bottoms make up this category. Solvent degreasing sludges contain at least 10 percent of the original solvent and distillation sludges normally contain 10 to 50 percent of the original solvent. These wastes usually have a high content of oil and grease or resins, with inorganic salt concentrations averaging 1 percent and concentrations of lead, zinc and cadmium up to 100 mg/l. Approximately 6 percent of the landfilled chlorinated solvents were solids, and 27 percent were sludges (Ref 46, 91).

2.1.4 Toxicology, Migration Potential and Persistence of Chlorinated Solvents

Except for the compound 1,1,2-trichloro - 1,2,2-trifluoroethane, the spent chlorinated solvent compounds are priority pollutants under Section 307 of the Clean Water Act. Toxicological data, migration potential, and persistence of each specific compound are explained in the following paragraphs. Tables 1 and 2 contain information on toxicity and physical properties. Some chlorinated solvents have been identified as carcinogens by the Carcinogen Assessment Group of the United States Environmental Protection Agency. Data are often lacking and knowledge is very incomplete on the toxicity associated with relatively low concentrations found in ground water and in air. All have been shown to be toxic to human or animal life either in the short or long term, however.

Studies on the migration of chemicals in the environment have recently been initiated. Results of pertinent studies which are available are discussed in Section 2.2.3, Leachate Migration/Liner Interception. Physical properties that indicate the potential for mobility in the environment include solubility in water, vapor pressure and the octonol/water coefficient. These are given in Table 2. Mobility potentials increase with increasing solubilities, vapor pressures and octonol/water coefficients, while the potential for adsorption by soil decreases. Persistence in the environment refers to the lack of potential for a chemical to break down into other compounds after exposure to the bacteria, ultraviolet radiation and oxygen present in the environment.

Tetrachloroethylene

Repeated exposure in rats and mice to tetrachloroethylene in air or by ingestion has resulted in central fatty deneration in the liver, increased kidney weights and toxic nephropathy. It also causes mild intoxication and liver dysfunction following chronic exposure to high levels associated with

TABLE 1

PHYSICAL PROPERTIES OF CHLORINATED SOLVENTS[a]

CHLORINATED SOLVENT	CHEMICAL FORMULA	DENSITY @ 20°C (g/ml)	VAPOR PRESSURE @ 20°C (mm Hg)	SOLUBILITY IN WATER @ 20°C (mg/l)	BOILING POINT °C	THRESHOLD ODOR CONCENTRATION (ppm)	OCTANOL/WATER PARTITION COEFFICIENT[b]
Tetrachloroethylene (Perchloroethylene)	CCl_2CCl_2	1.626 (20°)	14	150 (25°)	121.4	50	339
Trichloroethylene	CCl_2	1.46	60	1.10 (25°)	86.7	250	195
Methylene Chloride	CH_2CCl_2	1.326	349	20,000	40-42	150	20
1,1,1 - Trichloroethane	CH_3CH_3	1.35	100	4,400	71/81	400	158
Carbon Tetrachloride	CCl_4	1.59	90	800	76.7	200	
Chlorobenzene	C_6H_5Cl	1.107	8.8	500	132	0.22	690
1,1,2 - Trichloro - 1,2,2, Trifluoroethane	$CFCl_2CF_2Cl$	1.56 (25°)	270	-	48	68	100
O-Dichlorobenzene	$C_6H_4Cl_2$	1.305	1	100	179	50	2,400
Trichlorofluoromethane	CCl_3F	1.494 (17°)	687	1,100 (25°)	23.8	135	339

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[a] Unless otherwise noted, the data presented herein were taken from "Handbook of Environmental Data on Organic Chemicals", Karel Verschueren, 1977, Van Nostrand - Reinhold.

[b] Reference No. 91.

TABLE 2

TOXICOLOGICAL DATA FOR CHLORINATED SOLVENTS[a]

CHLORINATED SOLVENT	CARCINOGEN[b]	THRESHOLD LIMIT VALUES (ppm)		BIOLOGICAL EFFECTS	
		AVERAGE 8-HOUR 40 HR/WK	ACCEPTABLE CEILING LEVEL	MAN	RAT
Tetrachlorethylene	-	100	200		Inhalation: no pathological effects 70 ppm, 8 hr/day, 5 day/wk, 7 month Some pathological changes in liver and kidneys 230 ppm, 8 hr/day, 5 day/wk 7 month
Trichloroethylene	yes	100	200	Inhalation: supportable during 30 min: 379-372 ppm; full narcosis: 2500 - 6000 ppm; - eye irritation: 160 ppm	LC $_{50}$: 8000 ppm 4 hr No effect: 100 ppm 8 hr Oral toxicity: 3-5 ml/kg
Methylene Chloride	-	500	1,000		No pathology: 5000 ppm, 7 hr/day 5 day/wk, 6 wk
1,1,1 - Trichoroethane	-	350		Eye irritation, headache: 500 ppm, 180 min	LC^{c} $_{50}$: 24,000 ppm, 1 hr; 18,000 ppm, 3 hr; 14,000 ppm, 7 hr LD^{d} $_{50}$: single oral 10.3 - 12.3 g/kg
Carbon Tetrachloride	yes	10	25	Severe toxic effects: 2,000 ppm, 60 min; Symptoms of illness: 500 ppm, unsatisfactory >50 ppm	LD $_{50}$: 2.92 g/kg Inhalation: no effects, 3,000 ppm, 6 hr; 50 ppm, 7 hr
Chlorobenzene	-	75		Severe toxic effects: 400 ppm, 60 min Symptoms of illness: 200 ppm, 60 min Unsatisfactory: >75 ppm, 60 min	LD $_{50}$: 2.19 g/kg LC $_{50}$: 12,000 ppm, 30 min
1,1,2 - Trichloro - 1,2,2, - Trifluoromethane	- -	1,000		Inhalation: no effect level 1000 ppm, 6 hr/day 5 day 1,500 ppm, 2-3/4 hr	Inhalation: no effect: 2500 ppm, 7 hr/day, 30 day
Dichlorobenzene	-	50		Severe toxic effects: 300 ppm, 60 min Symptoms of illness: 100 ppm Unsatisfactory: 25 ppm No injury at 1-44 ppm	Inhalation: no effect 93 ppm 7 hr/day 5 day/wk, 6-7 month Survived: 977 ppm, 2 hr Succumbed: 977 ppm, 7 hr.
Trichlorofluoromethane	-	1,000		Inhalation: 3000 - 10,000 ppm inhaled entirely after 3-10 min	LD_{50}: 100,000 ppm, 30 min

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[a] Unless otherwise noted, the data presented herein were taken from "Handbook of Environmental Data on Organic Chemicals", Karel Verschueren, 1977, Van Nostrand - Reinhold.

[b] Reference No. 91 .

[c] LC_{50} = the calculated concentration expected to kill 50 percent of the population of experimental animals during a 4-hour exposure when administered by the respiratory route.

[d] LD_{50} = the calculated dose of a chemical substance expected to kill 50 percent of the population of experimental animals exposed through a route other than respiratory.

certain industries. Tetrachloroethylene is mobile and persistent in the environment and is found in trace amounts in water, aquatic organisms, air, foodstuffs, and humans (Ref 91). In 1974, at eight locations in five industrial states, the concentrations of tetrachloroethylene ranged from 1.2 ppb (parts per billion) in the urban areas to less than 0.02 ppb in rural areas. Chlorination at sewage treatment plants has resulted in slightly enhanced levels in water (Ref 31).

Trichloroethylene

Trichloroethylene is on the United States Environmental Protection Agency's list of chemicals which have demonstrated substantial evidence of carcinogenicity. Both acute and chronic exposure to high levels produce central nervous system depression and other neurological effects. Trichloroethylene also causes some kidney and liver damage. It is mobile and persistent in the environment (Ref 91). Typical concentrations of trichloro-ethylene at eight locations in five U.S. states in 1974 ranged from 180 ppt (parts per trillion) in urban areas to less than 20 ppt in rural areas. Slightly enhanced levels have been observed after chlorination of waters at sewage treatment plants (Ref 31).

Methylene Chloride

Methylene chloride is also referred to as dichloromethane. In humans it is a central nervous system depressant resulting in narcosis at high concentrations and impaired task performance. On the basis of present evidence, methylene chloride cannot be firmly identified as a carcinogen in humans or animals. It is a stable compound and may migrate in the environment (Ref 91).

1,1,1 Trichloroethane

1.1.1 Trichloroethane is also known as methyl chloroform. It affects the human central nervous system functions in reaction time, perceptual speed, manual dexterity and equilibrium. Studies of animal reactions have shown toxic effects on the central nervous system, cardiovascular system, and pulmonary system and damage to liver and kidneys. 1,1,1 Trichloroethane is highly mobile and persistent in ground water (Ref 91). Methyl chloroform has been found in the stratosphere at an average level of 80 ppt. Once in tne stratosphere, it photolyzes to products which can deplete ozone, leading to increases in skin cancer and other effects (Ref 31).

Carbon Tetrachloride

Carbon tetrachloride has also been included on the USEAP's list of chemicals which have demonstrated substantial evidence of carcinogenicity. It has also been shown to cause liver and kidney damage, biochemical changes in liver function and neurological damage. Carbon tetrachloride is very persistent in the environment (Ref 91). It has been found in foodstuffs including produce (0.2-14 ppm), meat (7-9 ppm), oils and fats (0.7-18 ppm), beverages (0.2-6 ppm), and fruit and vegetables (3-8 ppm. Carbon tetrachloride has also been found in 10 percent of the U.S. drinking water supplies at levels up to 3 ppb in a USEAP survey of 80 cities. Concentrates of carbon tetrachloride at sub-ppb levels in urban areas and much higher concentration in urban areas of the United States have been reported (Ref 31).

Chlorobenzene

Chlorobenzene has been found to produce histopathological changes in the lungs, liver and kidneys following its inhalation by rats, rabbits and guinea pigs. There have not been any studies conducted yet to evaluate the mutogenic, teratogenic or carcinogenic potential of chlorobenzene. It is persistent and may migrate (Ref 91).

1,1,1-Trichloro-1,2,2-Trifluoroethane and Trichlorofluoromethane

Trichlorotrifluoroethane and trichlorofluoromethane belong to the class of chlorofluorocarbon solvents which are highly volatile but which are not a direct toxicity hazard. As they volatize they mix with the atmosphere and move slowly into the stratosphere. Once in the stratosphere, however, chlorofluorcarbons are decomposed by ultraviolet radiation and release chlorine atoms which combine with and deplete ozone from the atmosphere. Ozone reduction leads to increases in skin cancer, induces climate changes and has other effects (Ref 91).

Ortho-Dichlorobenzene

O-Dichlorobenzene, or 1,2-dichlorobenzene is highly bioaccumulative. It may migrate and is persistent in the environment. Dichlorobenzene has a moderate toxicity via inhalation and oral routes, mainly to the liver and kidneys. It can also act as a central nervous system depressant after short periods of exposure (Ref 91).

2.2 CONSIDERATIONS FOR LAND DISPOSAL

Until recently, the management of solid waste was largely a personal matter. However, public awareness of waste management practices bloomed after the exposure of past improper disposal practices, such as Love Canal and Valley of the Drums. The passage of the Resource Conservation and Recovery

Act in 1976 has had far reaching impacts on the management of hazardous wastes from generation to destruction and disposal. Primary goals of the Act have been to encourage the recycle/re-use of hazardous wastes, conservation of resources, waste segregation and reduction, and control of the storage, transportation, treatment, destruction and disposal of hazardous wastes in order to minimize the potential for interaction and release of hazardous constituents into the environment.

Many gaps in the knowledge and understanding of the physical, chemical and toxicological effects of hazardous wastes exist, consequently, decisions concerning the management of these wastes must necessarily be conservative. The full cost of the improper disposal of hazardous wastes is extremely difficult to quantify. We have become aware of the resulting economic costs of removal of wastes and contaminated soils, the collection and treatment of leachate and contaminated ground water, the violent reactions that may occur when some wastes are combined and the effects on human health and the surrounding environment.

Landfilling is currently and will probably remain the predominant method for the disposal of hazardous wastes (Ref 1). Current practices required by RCRA regulations in making land disposal more secure involve waste segratation and the use of a barrier between the wastes and the ground or surface waters. Proper waste segregation is conducted to reduce the potential for interaction between wastes that may result in a fire, explosion, air emissions, increase in leachate production or increase in the concentration or number of hazardous constituents present in leachate. Barriers between wastes and the environment may be in the form of a landfill liner as discussed below, or as a waste solidifcation or stabilization technique as discussed in Section 1.5.6.

2.2.1 Segregation of Waste Chlorinated Solvents

The proper waste segregation necessary for secure land disposal can be accomplished easily once the potential hazards are recognized. Appendix V of 40 CFR 265 in the Monday, May 19, 1980 Federal Register contains examples of hazardous wastes which should not be mixed. These groups of incompatible wastes are reproduced in Table 3. Group 4-A wastes, which include halogenated hydrocarbons, (where chlorinated solvents belong) should not be mixed with concentrated Group 1-A and 1-B wastes, which are alkaline and acidic, respectively, or with Group 2-A wastes, the reactive metals and metal oxides (Aluminum, Beryllium, Calcium, Lithium, Magnesium, Potassium, Sodium and Zinc powder). The mixing of these has the potential consequence of fire, explosion or heat generation or the generation of flammable or toxic gases. In addition, Group 4-A wastes should not be mixed with Group 6-A wastes which are strong oxidizers due to the potential for fire, explosion or violent reaction. Long-term effects of mixing chlorinated solvents with acidic solutions also include the potential for leaching heavy metals from the waste solvent. All indications are that waste segregation in landfills can be easily performed.

2.2.2 Leachate Migration/Liner Interception

Leachate from the landfilling of wastes may be the liquid constituents of the waste itself or the liquids generated from waste or water percolating through the landfill (Ref 1). There is not much information currently available on the ultimate fate of these liquids in regard to factors such

TABLE 3

INCOMPATIBLE WASTE GROUPS*

Group 1-A	Group 1-B
Acetylene sludge	Acid sludge
Akaline caustic liquids	Acid and water
Alkaline cleaner	Battery acid
Alkaline corrosive liquids	Chemical cleaners
Alkaline corrosive battery fluid	Electrolyte, acid
Caustic wastewater	Etching acid liquid or solvent
Lime sludges and other corrosive alkalies	Pickling liquor and other corrosive acids
Lime wastewater	Spent acid
Lime and water	Spent mixed acid
Spent caustic	Spent sulfuric acid

- Potential consequences: heat generation; violent reaction.

Group 2-A	Group 2-B
Aluminum	Any waste in Group 1-A or 1-B
Berylium	
Calcium	
Lithium	
Magnesium	
Potassium	
Sodium	
Zinc powder	
Other reactive metals and metal hydrides	

- Potential consequences: fire or explosion; generation of flammable hydrogen gas.

Group 3-A	Group 3-B
Alcohols	Any concentrated waste in Groups 1-A or 1-B
Water	Calcium
	Lithium
	Metal hydrides
	Potassium
	SO_2Cl_2 PCl_3 CH_2SiCl_3

- Potential consequences: fire explosion, or heat generation; generation of flammable or toxic gases.

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*Federal Register, May 19, 1980, Volume 45, Number 98.

TABLE 3 (continued)

INCOMPATIBLE WASTE GROUPS

Group 4-A	Group 4-B
Alcohols Aldehydes Halogenated hydrocarbons Nitrated hydrocarbons Unsaturated hydrocarbons Other reactive organic compounds and solvents	Concentrated Group 1-A or 1-B wastes Group 2-A wastes

- Potential consequences: fire, explosion, or violent reaction.

Group 5-A	Group 5-B
Spent cyanide and sulfide solutions	Group 1-B wastes

- Potential consequences: generation of toxic hydrogen cyanide or hydrogen cyanide or hydrogen sulfide gas.

Group 6-A	Group 6-B
Chlorates Chlorine Chlorites Chromic acid Hyphochlorites Nitrates Nitric acid, fuming Perchlorates Permanganates Peroxides Other strong oxidizers	Acetic acid and other organic acids Concentrated mineral acids Group 2-A wastes Group 4-A wastes Other flammable and combustible wastes

- Potential consequences: fire, explosion, or violent reaction.

as potential for desorption from solids, and gravity flow through the waste. The adsorption of liquid waste on a solid matrix often does not allow the retention of liquids against gravitational forces once they are stocked in a landfill (Ref 2). This means that chlorinated solvents currently being mixed with general refuse or adsorbant material may only be temporarily absorbed and may migrate through the landfill cell over time.

Leachates vary considerably in chemical composition. Leachates generated by the organic fluids in hazardous wastes can be separated into four classes: acids, bases, neutral polar, and neutral non-polar materials (Ref 24). Chlorinated solvents usually contain polar or non-polar chlorinated hydrocarbons but other organics present in the waste and in surrounding wastes in a landfill cell may make the resulting leachate fall into other classes. Characteristics of the leachate greatly affect the migration of chemical species in soil, liners and fluids. Results of research conducted on chlorinated solvents or on similar chlorinated hydrocarbons are presented below.

Studies on the migration of two halogenated hydrocarbons, polybrominated biphenyl (PBBs) and hexachlorobenzene (HCB) show that although they are immobile in soils when leached with distilled water, they become highly mobile when leached with organic solvents (Ref 38).

Another chlorinated hydrocarbon, hexachlorocyclopentadiene, has been observed to have a strong affinity for soil and a low solubility in distilled water. Its absorption in soil and potential mobility through soil are highly dependant upon the total organic carbon content of the soil. The migration of iron, cadmium, nickel and zinc in soils was observed to increase with concentrations of total organic carbon, salts and iron in studies performed by Fuller (Ref 33,34).

Liners are placed in the bottoms and sides of landfills to intercept and contain leachate. Liners are usually constructed of clay and soil, concrete, asphalt, or polymeric membranes. The materials of construction differ significantly in physical and chemical properties, and consequently, in their resistance to leachates of varying characteristics.

Clay Liners

Historically, clay and soil liners have usually been used in hazardous or industrial waste landfills. Most clay liners contain either kaolinite, illite, or montmorillonite type clays. Studies on clay liners containing these clays have been conducted to identify cases where organic liquids may alter their permeability (Ref 1, 2, 12, 37). Four native clay soils containing one of the above clay types were evaluated by Anderson, Brown and Green by the traditional permeability test using a 0.01 normal solution of calcium sulfate in water and by a permeability test method developed by Brown and Anderson using leachates containing one of the four classes of organics (acid, base, neutral-polar and neutral non-polar). All four clay soils were found to qualify for use as the lining of hazardous waste disposal facilities based on permeability to water of less than 1 x 10-7 cm sec-1. However, these same soils underwent large permeability increases when permeated by combinations of basic, neutral polar and neutral non-polar organic fluids and showed the same potential for substantial permeability increases when exposed to concentrated organic acids (Ref 2). The permeabilities of tHe different clay types were found to increase by clay dissolution, volume changes (shrink/swell), soil piping or miscellaneous effects when exposed to organics in previous studies (1). Escher of Penn Environmental, believes that far less severe effects, if any should be expected from the generally more dilute forms normally expected in a secure landfill (Ref 49). Additional studies were conducted by Green, Lee and Jones on clay soils containing kaolinite, illite and montimorillonite with common solvents including carbon tetrachloride and trichloroethylene. Studies initially showed that the clays were virtually impervious to the solvents due to diffusion and convection through pores. After several days of exposure to the solvents, breakthrough phenomena were observed for carbon tetrachloride, benzene and xylene. The authors concluded that "from the observations, it can be concluded that any solvent that causes a clay to shrink appreciably during any shrink/swell experiment is a potential hazard when stored in a clay-lined disposal area. Even though such a solvent may move slowly through a wet clay by diffusion and convection, there is, in principle, a danger that it will eventually cause shrinking and cracking and thereby allow fluid transmission in bulk" (Ref 37).

Polymeric Membrane Liners

Studies have been conducted on synthetic (polymeric) membranes to identify possible failure mechanisms. Shultz and Miklas investigated liner installation practices necessary to minimize rips and tears. They found that proper installation required a suitably compacted sub-grade without any rocks, and adequate soil sterilization to prevent root or shoot growth through the liner. Care must be taken to use suitable adhesives in seams. The liners should not be stretched or folded and adequate cover materials must be used. Subsidence of rock, folds and stretching of the liner contribute to wear and tear. Also, a liner must be made of material that is compatible with the wastes-to be landfilled (Ref 76, 77).

Haxo investigated the interaction of selected lining materials with various hazardous wastes (no chlorinated solvents). He found that organic constituents are particularly aggressive to most of the liners considered for lining waste impoundments. Even in minor amounts in the fluid, organic compound can swell or dissolve the organics in liner materials and eventually may cause the failure of a liner. He observed that the liner materials lost elongation, became stiff or swelled when exposed to wastes for a long period of time (Ref 40, 41).

Admix Liners

Haxo also observed that admix liners such as hydraulic asphalt are generally not resistant to organic solvents and chemicals. Organics have been observed to weaken cement used for solidifcation/stabilization of wastes as well as other materials (Ref 41).

2.2.3 Cost of Land Disposal

Landfills receiving hazardous wastes in Illinois charge between $30 and $40 per 55 gallon drum received. Since chlorinated solvents are controversial due to toxicity, persistence and migration, the upper end of the cost scale can be assumed to apply to the landfilling of chlorinated solvents.

2.2.4 Environmental Consequences of Land Disposal

None of the liners researched recently are immune to attack by organics. Haxo has concluded that there does not appear to be any single lining material now commercially available which is suitable for long term impoundment of all wastes. Studies by others have shown the susceptibility of clay liners to shrink/swell and ultimate failure when exposed to organics over time.

Once a liner is leaking, leachate may enter ground or surface waters depending on its proximity to these waters and the permeability of the underlying soils to the leachate.

Chlorinated solvents have a fairly high potential for migration and persistence in the environment. Studies have shown many of these solvents to be carcinogenic, or at least, toxic to human and/or animals. Land disposal presents the greatest potential for migration of toxic compounds since, when compared to available alternatives, the compounds are not destroyed, will persist in the environment and have a fairly high potential to permeate through "secure" landfills.

2.3 EXISTING ALTERNATIVES TO LAND DISPOSAL IN ILLINOIS

The following subsections present detailed discussions of the alternatives to land disposal of chlorinated solvents. Table 4 presents a summary of the alternatives and the important differences between them.

2.3.1 Solvent Reclaiming/Recycling

There are several commercial solvent reclaimers in Illinois that accept chlorinated solvents. The extent of solvent recycling is highly market dependent with parameters such as sludge content, number of solvents mixed in a given waste and marketability of the resulting solvent determining the feasibility of reclamation. Only carbon tetrachloride, fluorocarbons, methylene chloride, perchloroethylene, trichloroethylene and 1,1,1-trichloroethane, of the chlorinated solvents, are usually reclaimed (Ref 83). One solvent reclaimer in Illinois further reduced the list to methylene chloride, trichloroethylene, perchloroethylene and 1,1,1-trichloroethane (Ref 66).

TABLE 4

COMPARISON OF LANDFILLING TO ALTERNATIVES

METHOD	TYPICAL COST PER 55 GALLONS (dollars)	APPLICABILITY TO CHLORINATED SOLVENTS	DESTRUCTION EFFICIENCY (percent)	REMAINING WASTES	ADVANTAGES	DISADVANTAGES
Landfilling	40	-	0	All	Current cost is low	Probability of liner failure and contamination of soils, water, and air
Solvent Recovery	-27 to -34	Relatively clean, non-mixed liquids	45	55 Percent becomes sludge, air emissions	Saves money, volume reduction of wastes	Air emissions
Incineration	118-237	All	99.99+	Ash or slag, contains heavy metals, water requires some treatment	Complete destruction of waste	More expensive in short-term
Coincineration	-	Limited to high BTU, low chlorine wastes	99.99+ demonstrated on some	Air emissions, ash	Saves fuel, complete destruction of some wastes	Air emissions
Wet Oxidation	38-77	Limited organic content	Partial	Increase in volume of water with lower concentration		Not efficient
Super Critical Water Reforming	550-1650 5.50-110 (established for future unit)	Not all have been demonstrated	99.99+ demonstrated on some	Slag with metal salts	Complete destruction of some wastes	Has not been proven full-scale
Deep Well Injection	4.40-7.70	Permitting constraints	0	Not applicable	Current cost is low	Possibility of material failure, intrusion into water or economic minerals
Solidification/ Stabilization	1.65-165	Limited organic content	0	Increases volume of waste		Subject to deterioration by organics, contamination of soils, water and air

The decrease in quantities of chlorinated solvents already being landfilled is partly attributed to more solvents being recycled/reclaimed. It is difficult to estimate the percentage of chlorinated solvents currently being landfilled that could be reclaimed since most reclaimers take and sell wastes on a case-by-case basis. Assuming that only liquids could be accepted reduces the acceptable quantity of solvents to 67 percent of the estimated total, or 83,000 gallons. Waste marketability, content of water and impurities, degree of mixing of solvents, etc., would further reduce this quantity.

Excess Capacity

Based on discussions with several chlorinated solvent reclaimers located in Illinois, there appears to be a sufficient recycling capacity to receive well over the quantity of chlorinated solvents currently being landfilled in Illinois (124,000 gallons), although only a fraction of the quantity is treatable by distillation (reclamation). The excess capacity may be as high as 3 million gallons per year. Discussions with four vendors revealed that current excess capacity is at least 2 1/2 million gallons per year (Ref 24, 54, 66, 70).

Remaining Residues

Approximately 55 percent of the incoming waste solvent will ultimately become a waste sludge from the mechanical separation or distillation step. Recycling/reclaiming is therefore not a destruction technique but a treatment/volume reduction method. Assuming that only 20 percent of the annually landfilled chlorinated solvents could be reclaimed, 89 percent of the total volume of wastes (80 percent plus 55 percent of the reclaimed as residues) would still require treatment.

Costs

Solvent reclaimers usually buy recyclable waste solvents and resell the recycled product to the same generator for 70 to 80 percent of the virgin price. It therefore does not cost the generator to have the solvent reclaimed. Reclaimers are located throughout the state and reclaimers located in the Chicago area appear to have the capacity to handle additional quantities now being landfilled.

2.3.2 Incinerators

Presently there are three commercial incinerators located in Illinois which receive chlorinated solvents. These are owned by SCA Chemical Services Company in Chicago, Trade Waste Incineration in Sauget (near St. Louis) and Alburn Incinerator in Chicago. Descriptions of the capabilities of the facilities are discussed below.

The incinerator owned by SCA Chemical Services has a total capacity of about 40,000 gallons per day and is currently operating at 25 to 30 percent of total. It is of rotary-kiln design with a liquid injection afterburner and scrubbers for control of pollutant emissions. The facility is permitted to receive chlorinated solvents and can handle up to 25 percent chlorine by weight in the feed. This is currently limited by the limestone scrubbing pollution control equipment and could be increased. Blending of wastes allows for the acceptance of wastes containing high ash, high organic chlorine and high concentrations of heavy metals (Ref 48). The rotary kiln design allows the acceptance of solids, sludges and liquid wastes (Ref 72).

The Trade Waste Incineration unit is permitted to receive chlorinated solvents. The unit has a 2000 lb/hr capacity with current average feed rate of 50 percent. It is of fixed hearth design and is equipped with an afterburner and water quench with Venturi scrubber for air-emissions control. TWI's incinerator is capable of handling solids, semi-solids, and liquids. Blending of wastes allows the treatment of wastes containing halogenated compounds and heavy metals (Ref 48). The incinerator serves a local market within a 500 mile radius of St. Louis (Ref 59, 81).

The Alburn Incinerator unit handles liquids and pumpable sludges. The unit is running at a state-limited capacity of 5000 gallons/day. Alburn is planning on increasing the capacity to 24,000 gallons/day; however, the unit is undergoing permit difficulties with the state. Chlorinated solvents are blended with other wastes in order to meet the operating limitation of 6 percent chlorine by weight (Ref 61).

Excess Capacity

It is difficult to determine the current excess capacity and future excess capacity of commercial incinerators in Illinois. These depend upon meeting permitting requirements in the present and future. At this time there is more than enough excess capacity to successfully destroy the quantity of chlorinated solvents currently being landfilled in Illinois. Over 3 million gallons of excess capacity currently exists for chlorinated solvents, allowing for maximum halogen content that can be accepted by each incinerator.

2.3.3 Other Facilities

Illinois does not have any other commercial facilities permitted to treat or dispose of chlorinated solvents. There is one non-commercial deep-well injection unit that disposes chlorinated pesticides but not chlorinated solvents.

2.3.4 Cost of Alternatives

Solvent reclamation does not normally cost the generator, it actually saves money in buying replacement solvents. Assuming that 45 percent of a recyclable solvent can be reclaimed, and that the generator can save $60 on a drum of solvent, the generator can save $27 per drum of recycled solvent (Ref 54).

Incineration prices charged by the three commercial facilities varied considerably from $40 to $194 per drum (Ref 59, 61, 72). Prices between $106 and $194 are consistent with literature values. This is considerably higher than the current cost of landfilling of $40 per drum.

2.3.5 Environmental Consequences of Alternatives

Solvent reclamation processes recover approximately 45 percent of the waste solvent. The remaining 55 percent becomes waste sludge containing over 50 percent solvent. Only liquids or nonmixtures are usually accepted for recycling by reclamation facilities. Solvent recycling is a volume reduction cost saving technique applicable to only a fraction of the chlorinated solvent wastes currently being landfilled. Air emissions result from storage and handling, mechanical separation, and purification steps. Emissions from the recycling of waste solvents include hydrocarbons and particulates (Ref 83) and are probably no greater than emissions of hydrocarbons and particulates from land disposal while mixing with general refuse and prior to daily cover of the landfill.

Incineration of the remaining wastes and waste sludges (from distillation sludges) eliminates essentially all chlorinated hydrocarbons. Wastewaters containing high concentrations of total dissolved solids can be pretreated before disposal at a publicly owned treatment plant. Remaining ash from the incinerator may contain up to 3 percent contaminants such as heavy metals. These can be landfilled in a hazardous waste disposal facility. One article reviewed described the ash as a glass-like slag which contained contaminants such as heavy metals in a nonleachable form (Ref 97). Only incinerators that operate at 99.99 percent plus efficiency can legally receive chlorinated solvents, making incineration combined with some solvent reclaiming an environmentally safe and desirable alternative with minimum waste generation and minimum possibilities for release into the environment.

3.0 BENEFITS

In the following section an attempt has been made to identify the benefits that can be expected to arise should the proposed regulation to prohibit the landfill disposal of chlorinated solvents be implemented, the groups that would be likely to receive those benefits, and the magnitude of the benefits. Some of the benefits, particularly those related to protection of human life and health, quantification of the magnitude of the benefits was not considered possible at this time in large part due to the uncertainties that surround the probabilities that events would occur that would endanger human life or health.

3.1 IDENTIFICATION OF IMPACTED POPULATION

Several groups may be expected to be the primary recipients of those benefits arising from the implementation of a regulation to prohibit the landfilling of chlorinated solvents (USEPA Hazardous Waste Numbers F001 and F002). These groups include:

- Persons residing near and persons working at landfills that currently accept chlorinated solvent wastes for disposal;
- Groups that consume water from either ground or surface water sources that could potentially be contaminated by those wastes;
- Owners and operators of incinerators capable of disposing of chlorinated solvents;
- Owners and operators of solvent reclamation facilities that have the capacity to accept increased quantities of chlorinated solvent suitable for reclamation that are currently being landfilled;
- Owners and operators of firms engaged in the transport of hazardous wastes;
- Those firms which generate waste solvents and those firms engaged in the landfilling of those wastes (this group is also included in the cost-impacted population, see Section 4.1); and
- Agencies of the Illinois state government responsible for the enforcement of hazardous waste regulations.

The benefits that each of these groups may be expected to receive will vary as to their nature and magnitude. The following discusses these factors.

3.2 ESTIMATED NATURE AND MAGNITUDE OF BENEFITS

3.2.1 Nature of the Benefits

It is anticipated that the benefits that could be derived from implementation of a ban on landfilling of chlorinated solvents would be:

- A decrease in the exposure of the population residing near landfills currently accepting chlorinated solvents for disposal to those wastes and a concomitant reduction in the risk that their health may be impaired as a result of these wastes entering the environment.
- An increase in the revenues of firms providing solvent reclamation, incineration, and transportation services.
- A decrease in the administrative expense to the State of Illinois in the enforcement and monitoring of hazardous waste regulations.
- Reduction in the potential for potable water supply contamination resulting from the leaching and migration of wastes from landfills.
- A decrease in the liability incurred by both generators of the wastes and landfill operators by reducing the potential for environmental degradation from these wastes.
- An increase in the potential serviceable life of the landfills currently receiving these wastes.

The estimated magnitude of these benefits and the relationship to the recipient group is discussed below. It is not expected that the proposed regulation will result in benefits to recreation except by decreasing the probability that surface water could become contaminated and result in an impairment of the use of those water bodies for recreational purposes.

3.2.2 Estimated Magnitude of Benefits

Many of the wastes identified in the regulation have been identified by the USEPA as being of a toxic nature. Among these wastes are tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon, tetrachloride, chlorobenzene, orthochlorobenzene, 1,1,1-trichloro-1,2,2-trifluoroethane, and trichloro-fluoromethane. In addition to the toxicity identified with these wastes, many have also been identified as or are suspected of being carcinogens. The toxicity of these wastes is discussed in Section 2.1.4. The banning of the landfill disposal of these wastes would reduce the exposure of the population residing near landfills that accept them and, thus, reduce the risk of that population to incurring the associated health-related effects.

Closely related to the reduced risk to humans from the banning of landfilled chlorinated solvents is the reduced potential for these wastes to contaminate sources of potable water. Water supplies are considered to be among the most prevalent routes for human exposure to hazardous wastes (Ref 56). Wastes enter these water supplies either through leaching into ground water or by runoff into surface waters. The encapsulation of solvents in steel drums provides a measure of protection; however, corrosion of the drums may eventually allow the release of solvents. The persistence of the wastes, discussed in Section 2.1.4, has been found to be very high, as has their mobility in the environment. Cessation of landfilling of these wastes would, thus, reduce the potential for their entry into ground and surface water supplies. The ash from incineration does, however, contain hazardous constituents that would be landfilled. These constituents are present in a form that does not avail itself to leaching and, thus, does not appear to present as great a risk as does landfilling of solvents.

As was stated earlier, data are often lacking or incomplete regarding the toxicity of these wastes relative to exposures of humans to low concentrations. Compounding this data problem is the lack of a widely accepted methodology for valuation of either loss of life or impairment of human health. Among the approaches that have been suggested for valuation of human life are the human capital approach (which is based on the future earnings potential of the individual), the insurance approach (based on the value of the life insurance held by the individual), the court awarded compensation approach (based on the amount awarded by the courts for fatal accidents), the implicit value approach (where each life is valued based upon past decisions affecting mortality), the portfolio approach (where changes in risk are compared to the range of risks confronting society), and the willingness to pay approach (which values life on the basis of the willingness to pay for reductions in risk) (Ref 82). While each of the approaches contains inherent methodological difficulties, it is interesting that several arrived at $200,000 as the value of a life. In the case of valuation of human health, most approaches resemble the human capital approach, adjusted for medical expenses. As an example, medical expenditures for severe kidney ailments (which have been associated with some of the listed wastes) have been estimated at $72,000 (for a kidney transplant) to $200,000 (for hospital administered dialysis) (Ref 3). Among the primary problems associated with the various approaches to health impairment are the inabilities of the approaches to compensate for suffering and the difficulties of valuation of non-wage earners. In the absence of epidemiological data and in light of the methodological difficulties associated with the various approaches to valuation, the quantification of benefits associated with the reduction in risk exposure is not possible. It should, however, be noted that the five landfills in Illinois that currently receive chlorinated solvents are located in Chicago, Joliet, Schaumburg, Sheffield, and Peoria, with those facilities in Joliet and Chicago representing over 75 percent of the total volume disposed. Thus, it would appear that reducing the potential for human exposure at these sites would conceivably benefit a large portion of the population of Illinois.

Reduction in the potential for ground water contamination could provide significant benefits through avoidance of costs to clean up a contaminated aquifer. In 1979, the cost associated with emergency containment and cleanup was estimated to be $3.2 million per site (Ref 3).

The implementation of the proposed regulation would also result in a transfer of income from those firms which operate landfills to those which operate incinerators or solvent reclamation facilities. This loss of income to landfill operators would, in part, be offset by the reduced likelihood of damage suits and liability for corrective actions that would be required should the banned waste be found to be entering ground water supplies.

An example of the magnitude of this liability may be found in the case of the Love Canal dumpsite, where cleanup, containment, and evacuation of the residents has resulted in the expenditure of $125 million which does not represent a final cost (Ref 3).

This reduced liability would be shared by both generators and landfill operators and would probably be reflected in the rates paid by those firms for environmental impairment insurance. Another group that would experience an increase in revenues are the transporters of the wastes. While the primary destination would, under the implementation of this regulation, shift from landfills to either solvent reclamation facilities or incinerators, the wastes generated by incineration would require transportation to lanfills thus increasing the total cost of haulage. Based upon the location of the incinerators and an average cost of $1.25 per mile to transport the materials, it is estimated that the benefit to transporters would range between $1,500 and $5,000, depending on the volume of wastes transported. This assessment assumes that the transporter would utilize 6,000 gallon trucks; should smaller trucks be utilized, then the benefit to the transporters could range as high as $13,000. This is due to the greater number of trips that would be required.

An analysis of the income transfers and costs of disposal is presented in Section 4.2.

It is possible that the costs of enforcement of hazardous waste regulations by state agencies would also be reduced. This reduction would arise from the implementation of an unambiguous rule that would allow enforcement officials to avoid the time consuming monitoring of chlorinated solvent waste streams by generator size and by whether the waste disposed is in a liquid or solid form. By stating the disposal regulation in such unambiguous terms as the prohibition of landfilling all chlorinated solvents, enforcement action would be initiated by the identified or suspected presence of the waste at a landfill site. The savings that would be attributable to this regulation are not readily identifiable; however, it is likely that they will exceed the $0.01 per gallon that is currently levied against the landfill operator. This loss of revenue to the State would be $1,240, assuming the 1982-volume case, and $4,100, assuming the 1980-volume case. If the regulation reduces the amount of time required by State officals to monitor the activities of five landfills by one man-year, the net benefit would be between $46,760 and $43,900, depending on the volume of wastes. This estimation of benefit assumes that a cost to the State of $4,000 per man-month (a figure consistent with the average wage as recorded by the Department of Commerce and Community Affairs), or $48,000 per year (with the inclusion of overhead and payroll costs and support costs).

3.3 SECONDARY BENEFITS

The secondary benefits that may accrue as a result of the proposed regulation are not anticipated to be of significance.

4.0 COSTS

The following analysis of the costs associated with the implementation of the proposed regulation is based upon an examination of current landfill disposal costs, an estimate of the quantities of wastes that would require disposal, and the examination of feasible alternatives to landfill disposal of chlorinated solvents. The projection of the quantities of wastes that are likely to require disposal utilizes the amounts generated in 1982 as lower range estimates and the amounts generated in 1980 as upper range estimates. It was felt that this would adequately reflect both the effects of reduced economic activity that is currently being experienced and the effects of other regulations on the quantities of wastes being generated. The costs are, thus, presented as ranges within which the future cost of the regulation can be expected to fall.

4.1 IDENTIFICATION OF THE COST-IMPACTED POPULATION

Two groups comprise the population that will primarily be cost-impacted by the proposed regulation: those who generate chlorinated solvents for disposal in landfills and the owners and operators of landfills receiving chlorinated solvents as waste streams. Through the increased costs of disposal that would be incurred by these groups in the event of the regulation prohibiting the landfilling of chlorinated solvents, another group, those who are consumers of the goods and services produced by the generators, will also be impacted, primarily through increases in the prices sought for those goods and services.

The following section describes the nature of the cost impacts that are likely to be realized through the implementation of this regulation and the magnitude of those cost impacts.

4.2 NATURE AND MAGNITUDE OF COSTS

4.2.1 Nature of Costs

Records of the listed wastes and estimates of the halogenated portion of those wastes indicate that, in 1982, approximately 124,000 gallons of chlorinated solvents were landfilled. This is a significant decrease from the 1980 volume of 410,000, due in part to two significant events during the interim. First, the State of Illinois prohibited the disposal of chlorinated solvents in a free-liquid form in 1982 and, second, the overall quantity of wastes has decreased in response to the slowing of the economy as a result of the current recession. In light of the first event, it appears unlikely that the 1980 volume will be reached in the absence of significant growth in the economy, particularly in those sectors responsible for the generation of chlorinated solvent wastes. The groups responsible for much of the generation of these wastes include dry cleaning, metal fabricating and finishing, primary metals production, machinery, electrical equipment, and transportation equipment. These groups utilize chlorinated solvents as cleaning and degreasing agents.

The primary impact to this group of waste generators resulting from the proposed regulation will be to increase their cost of disposal, an increase which can be expected to be passed through to consumers whenever possible. The magnitude of this cost impact is discussed below.

The second group that will be impacted by the proposed regulation are the owners and operators of landfills accepting chlorinated solvent wastes. This group will lose that portion of their revenue that was derived from the disposal of those wastes. Also losing revenue will be the State of Illinois which charges fees to landfill operators based on the volume of wastes disposed. The monies derived from the buying of these fees are distributed to the State Hazardous Waste Fund (75 percent) and to the State Hazardous Waste Research Fund (25 percent) (Ref 13).

4.2.2 Magnitude of Costs

As stated above, 124,000 gallons of chlorinated solvents are estimated to be disposed of at landfills in 1982. Based upon a survey conducted to determine the current cost of landfilling, it has been estimated that the average cost is $40 per 55-gallon drum; although some estimates range as low as $30 per drum. Thus, it is estimated that the current cost to industry to landfill chlorinated solvent is $90,000 (124,000 gallons per year divided by 55 gallons per drum times $40 per drum). The upper bound of the cost to industry, under the assumption that the 1980 volume is an upper limit that is realizable in the near future, to landfill chlorinated solvents would be $300,000 (410,000 gallons per year divided by 55 gallons per drum times $40 per drum). Both of these estimates are exclusive of transportation costs.

An equal allocation of these costs to the population of generators (the population is 930) would result in an annual cost to each firm (irrespective of volume generated) of $97, under the 1982-volume generated case, and $322 under the 1980-volume generated case.

The revenues derived by landfill operators to dispose of chlorinated solvents in 1982 is expected to be $90,000 (see above). There are 6 landfills in the State of Illinois permitted to receive chlorinated solvent wastes, although, in practice, only five sites do so. These sites, the volumes that each handle, and the estimated revenue losses are shown in Table 5.

The volume of revenue loss attributable to implementation of the proposed regulation should be considered in light of the total volume of hazardous wastes landfilled at those sites. It has been estimated that the volume of wastes disposed in 1980 was almost 95 million gallons, while in 1982 the volume was estimated to be 29 million gallons. Thus, chlorinated solvents represent 0.4 percent of the wastes being landfilled in Illinois.

The State of Illinois will also lose revenues by the implementation of this proposed regulation. It collects a fee of $0.01 per gallon of waste disposed from operators of hazardous waste facilities. It is estimated that the revenue loss to the state would range between $1,240 and $4,100 per year, depending on the volume of chlorinated solvents generated but not landfilled. It should be noted that under the provisions of P.L. 82-572, landfilling in the State of Illinois will be prohibited after 1987 unless a demonstration is made that no other feasible alternative to that method of disposal exists.

In the absence of further regulation of landfill practices by the State of Illinois, the Interim Standards developed by USEPA will apply. Under the provisions of these standards, the costs per drum of landfilling will increase to $45/drum if detection monitoring is instituted; to $55/drum if compliance monitoring is instituted; and between $65 to $75/drum if corrective action is found to be required (Ref 44).

TABLE 5

ESTIMATED REVENUE LOSSES

SITE	OPERATOR	ESTIMATED 1982 VOLUME	PERCENT OF STATE TOTAL	ESTIMATED REVENUE LOSS	
				1982-VOLUME CASE	1980-VOLUME CASE
Joliet/ESC	Waste Management Inc.	80,000	64.2	$58,200	$192,300
Sheffield/ Nuclear No. 2	U.S. Ecology (NECO)	20,000	15.8	$14,500	$47,100
Chicago/ CID No. 2	Waste Management Inc.	11,000	14.4	$13,100	$42,900
Davis Junction	Browing Ferris Industries	6,000	5.0	$4,400	$14,900
Peoria/Peoria Disposal No. 1	Peoria Disposal Company	750	0.6	$500	$1,800

Note: The data presented in this table were obtained from IEPA files and discussions with IEPA officials and the landfill operators.

Alternatives to Landfilling

In the State of Illinois, there are two existing feasible alternatives to landfilling of chlorinated solvents: solvent recovery and incineration of wastes. In the event that increased use is made of solvent recovery, the sludges resulting from waste volume reduction would also be prohibited from landfills and, thus, would need to be incinerated.

The decrease in chlorinated solvents being lanfilled in Illinois between 1980 and 1982 is partly attributable to an increase in the solvents being reclaimed. The volume increase that could be realized by the implementation of a ban on landfilling, however, is difficult to assess, in part because of the stringency of the quality of solvents that reclaimers will accept (preferably liquids and non-mixtures with high chlorine content) and the demand for reclaimed solvents will limit the acceptance of these products in the marketplace. As was stated in Section 2.1.3, approximately 67 percent of the chlorinated solvents currently lanfilled are in a liquid form. It appears likely that a portion of this (20 percent) represents the upper limit that reclaimers would accept. Thus, a maximum of between 25,000 and 82,000 gallons per year would be accepted under the 1982-volume and 1980-volume (124,000 gallons and 410,000 gallons, respectively) cases. The lower limit would assume that the market is saturated and that no further volumes would be reclaimed. In addition, only 45 percent of the volume of the solvents are reclaimed, the remaining 55 percent are wastes. This will result in 89 percent of the total solvents generated requiring another form of treatment.

As solvent reclaimers typically purchase waste solvents and resell the recycled product to the same firm at 70 to 80 percent of the cost of virgin solvents, there is no cost to the solvent generator. Typical savings of $30.50 per drum were reported in the survey made.

There are presently three commercial incinerators operating in the State of Illinois which will accept chlorinated solvents. The estimated cost of incineration at these facilities is between $40 and $194 per drum. These estimates appear to be consistent with the estimates of $106 and $194 per drum quoted in the literature (Ref 5, 52, 88, 98). Shown on Table 6 are the estimated costs of incineration of chlorinated solvents. These estimated costs are based on two volume cases and on cases with and without recycling. In the recylcing case, it has been assumed that a total of 89 percent of the total volume would be incinerated (that portion which was not acceptable to reclaimers and the sludges from reclamation). Also assumed in that case would be a cost recovery of 80 percent of the price of virgin solvent (approximately $3.50/gallon). Another potential source of cost reduction would be through co-incineration and the sale of steam generated during the combustion process. The extent and degree to which a market exists for such sales, however, is somewhat doubtful in light of its not having been implemented by the operators of these incineration facilities.

4.3 SECONDARY ECONOMIC BENEFITS

It is anticipated that, given the small magnitude of the estimated primary costs, that the secondary economic costs will not be significant.

TABLE 6

ESTIMATED COSTS OF ALTERNATIVES

	ESTIMATED 1982-VOLUME CASE (124,000 gallon/year)	ESTIMATED 1980-VOLUME CASE (410,000 gallon/year)
All wastes direct to incinerator no recycling $106/drum	$240,000	$790,000
All wastes direct to incinerator no recylcing $194/drum	$440,000	$1,450,000
20 Percent wastes recycled 80 percent direct to incinerator $106/drum	$165,000	$545,000
20 Percent wastes recycled 80 percent dfirect to incinerator $194 drum	$340,000	$1,130,000

Note: The data presented in this table were obtained from IEPA files and discussions with IEPA officials and the landfill operators. The costs presented in this table may contain slight differences due to round off of quantities in intermediate steps. See Section 4.2.2 for a discussion of how the calculations were performed.

5.0 COMPARISON OF BENEFITS AND COSTS

5.1 SUMMARY OF BENEFITS AND COSTS

As was shown in Chapter 4.0, the costs of landfilling, as currently practiced, are estimated to range between $90,000 per year and $300,000 per year. This assumes a disposal cost of $40 per drum at differing disposal quantities. The cost of incineration without any recycling of chlorinated solvents was estimated to range between $240,000 and $1,450,000 depending on the cost of incineration and disposal quantity assumed. Thus, the incremental cost associated with implementing the prohibition may be expected to be $150,000 per year for the 1982-volume case of 124,000 gallons per year and $1,150,000 for the 1980-volume case of 410,000 gallons per year. These ranges equal a potential incremental cost per gallon of waste disposed of $2.80 under the high cost incineration scenario to $1.21 per gallon under the low cost incineration scenario. If these costs were allocated equally among generators, of which there are 930, the cost per year per generator would be incurred through a prohibition or the landfilling of those wastes is negligible (Ref 45).

The total costs of implementing the proposed regulation to prohibit the landfilling of chlorinated solvents are largely dependent on the quantities of wastes to be disposed and the costs of the disposal methods available as alternatives to landfilling. As discussed in previous sections, the quantity of chlorinated solvents landfilled in Illinois declined from 410,000 gallons in 1980 to 124,000 gallons in 1982; the result of a ban on the landfilling of free liquids in 1982 and the current recession, which has reduced the quantities of solvents being generated. This range represents the minimum and the maximum quantities that are likely to be generated in Illinois prior to the implementation of a ban on landfilling. It is unlikely that the upper bound will be reached, however, given the expected slow rate of recovery being forecast for the economy. To achieve 410,000 gallons of wastes to be disposed from the current level of 124,000 gallons would require a growth rate in excess of 15 percent per year throughout the 1980's.

In addition to the technological alternatives to the landfilling of waste solvents, there exists several institutional alternatives. Among which are the subsitution of alternative products by the users of solvents increased use of the Waste Exchange that has been established by the state of Illinois, and increased use of specialty suppliers of solvents. The substitution of other products for chlorinated solvents does not appear to be very likely unless the costs of disposal become extremely high. Increased use of the Waste Exchange is likely only to the extent that a market exists for those products. It is likely, however, that increased use of specialty suppliers (those firms that supply the consumer with unmixed solvents and retain complete responsibility for their product, including transport, reclaiming, and ultimate disposal). This may be attractive to consumers who wish to divest themselves of responsibility for the disposition of the solvents although retain responsibility only for preventing negligence at their facility.

The benefits that would be expected to accrue and the groups that would be the primary recipients of those benefits are discussed in Chapter 3.0 and may be summarized as:

- A decrease in the exposure of the population residing near landfills currently accepting chlorinated solvents for disposal to those wastes and a concomitant reduction in the risk that their health may be impaired as a result of these wastes entering the environment.

- An increase in the revenues of firms providing solvent reclamation, incineration, and transportation services.
- A decrease in the administrative expenses to the State of Illinois in the enforcement and monitoring of hazardous waste regulations.
- Reduced potential for potable water supply contamination resulting from the leaching and migration of wastes from landfills.
- A decrease in the liability incurred by both generators of the wastes and landfill operators by reducing the potential for environmental degradation from these wastes.
- An increase in the potential serviceable life of the landfills currently receiving these wastes.

The difficulties that are associated with valuation of these benefits are described in Section 3.0. Many are directly related to the probability of a contaminating event occurring and, thus, are dependent on the degree to which the decision-making body ad the general population are risk-averse (that is, the degree to which the community desires to avoid the problems associated with waste disposal). In general, the reduced administrative expense to the state of Illinois approaches the increased cost that would result assuming the lower quantity generation of 1982 ($50,000 versus $150,000). The avoidance of any of the potential problems would significantly increase this amount.

5.2 DISTRIBUTIONAL EFFECTS

The primary distributional effects resulting from implementation of the proposed regulation are the transfer of income from the owners and operators of landfills to the owners and operators of incinerators and solvent reclaimation facilities, which are discussed in Section 4.0 of this report, and the distribution of cost increases among the users of chlorinated solvents. It has been estimated, based upon lists of generators of wastes in the State of Illinois, that six industries account for 70 percent of the waste solvents generated. These industries are: chemicals and allied products (55 percent), petroleum refining (6 percent), primary metals (6 percent), fabricated metals (1.1 percent), machinery (3.5 percent), and electrical equipment (1 percent). the diversity of these industries and the numbers of companies engaged in each do not indicate that a small group of firms will bear an inordinate share of the increased cost.

6.0 BIBLIOGRAPHY

1. Anderson, David, and Brown, K.W., 1981, Organic leachate effects on the permeability of clay liners. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 119-130.

2. Anderson, David, Brown, K.W., and Green, Jan, 1982, Effect of organic fluids on the permeability of clay soil liners. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 179-190.

3. Anderson, R.F., and Greenberg, M.R., 1982. Hazardous waste facility siting. APA Journal, Spring 1982, p. 204-218.

4. Azewski, Tom, 1982, Chemical Waste Management, private communications (November 22).

5. Basta, Nicholas, 1982, Firms avidly seek new hazardous-waste treatment routes. Chemical Engineering, September 6, 1982, p. 53-57.

6. Batelle Columbus Labs, 1976. Assessment of industrial hazardous waste practices: electroplating and metal finishing industries - job shops. US Environmental Protection Agency, Washington, D.C.

7. Batelle Memorial Institute, 1974. Program for the management of Hazardous wastes. US Environmental Protection Agency, Washington, D.C.

8. Block, Bob, 1982, Baron Blakeslee, private communication (November 23).

9. Bonner, T.A., and others, 1981, Engineering handbook for hazardous waste incineration. Industrial Environmental Research Laboratory, Office of Environmental Engineering and Technology, U.S. Environmental Protection Agency, Cincinnati, Ohio, SW-889.

10. Brenner, Walter, and Rugg, Barry, 1982, Exploratory studies on encapsulation of selected hazardous wastes with sulfur-asphalt blends. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 315-326.

11. Briedenbach, Andrew W., Lederman, Peter B., and Pojasek, Robert B., 1981, Hazardous waste management: disappointment of the seventies, expectations of the eighties. Water Pollution Control Federation Journal, vol. 53, no. 2, p. 152-154.

12. Brown, K.W., and Anderson, David, 1980, Effect of organic chemicals on clay liner permeability, a review of the literature. Proceedings - Sixth Annual Research Symposium, Disposal of Hazardous Waste, Chicago, Illinois, March 17-20, 1980, EPA 600/9-80-010, p. 123-134.

13. Bulanowski, G.A., Lazarus, G.H., Morandi, L., and Steeler, J. H., 1981. A survey and analysis of state policy options to encourage alternative to land disposal of hazardous waste. National Conference of State Legislatures, Denver, CO.

14. Chemical Week, 1980, Dravo thinks it has found a better way to burn waste. Chemical Week, August 27, 1980, p. 38.

15. _____, 1980, Using supercritical water to destroy tough wastes. Chemical Week, vol. 127, no. 9, p. 38.

16. Citizens for a Better Environment, 1982, First Amended Proposal for Adoption of Sanitary Landfill Regulation, February 2.

17. Chou, Sheng-Fu J., Fisher, Barry W., and Griffin, Robert A., 1981, Aqueous chemistry and adsorption of hexachlorocyclopentadiene by earth materials. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 29-42.

18. Chou, Sheng-Fu J., Griffin, Robert A., and Chou, Mei-In M., 1982, Effect of soluble salts and caustic soda on solubility and adsorption of hexachlorocyclopentadiene. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 137-149.

19. Cole, Philip, and Merletti, Franco, 1980, Chemical agents and occupational cancer. Journal of Environmental Pathology and Toxicology, vol. 3, p. 399-417.

20. Crump, Kenny S., and Guess, Harry A., 1980, Drinking water and cancer: review of recent findings and assessment of risks. Council on Environmental Quality, Washington, D.C.

21. Dallaire, Gene, 1981, Hazardous waste management in California: lessons for the U.S. Civil Engineering, April, 1981, p. 53-56.

22. Dragun, James, and Helling, Charles S., 1981, Evaluation of molecular modelling techniques to estimate the mobility of organic chemicals in soils: II. water solubility and the molecular fragment mobility coefficient. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 58-70.

23. _____, 1982, Soil- and clay-catalyzed reaction: I. physiochemical and structural relationships of organic chemicals undergoing free-radical oxidation. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 106-121.

24. Durakovich, Dave, 1982, Custom Organics, Inc., private communication (November 23).

25. Edwards, Barbara H. and Paullin, John N., 1980, Emerging technologies for the destruction of hazardous wastes: molten salt combustion. Proceedings - Sixth Annual Research Symposium, Treatment of Hazardous Waste, Chicago, Illinois, March 17-20, 1980, p. 77-85.

26. Edwards, Barbara H., Paullin, John N., and Coghlan-Jordan, Kathleen, 1981, Emerging technologies for the destruction of hazardous wastes: ultraviolet/ozone destruction. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 265-271.

27. Edwards, B.H., Paullin, J.N., and Coghlin-Jordan, K., 1982. Emerging technologies for the control of hazardous waste. US Environmental Protection Agency, Washington, D.C.

28. Environmental Science and Technology, 1979, Needed: hazardous waste disposal (but not in my backyard). Environmental Science and Technology, vol. 13, no. 8, p. 913-915.

29. Federal Register, July 26, 1982. 32274:32349.

30. Federal Register, May 19, 1980. 40 CFR 261.3.

31. Fishbein, Lawrence, 1979, Potential halogenated industrial carcinogenic and mutagenic chemicals, halogenated saturated hydrocarbons. The Science of the Total Environment, vol. 11, no. 2, p. 111-195.

32. Fuller, Wallace H., 1982, Methods for conducting soil column tests to predict pollutant migration. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 87-105.

33. Fuller, W.H., and others, 1980, Influence of leachate quality on soil attenuation of metals. Proceedings - Sixth Annual Research Symposium, Treatment of Hazardous Waste, Chicago, Illinois, March 17-20, 1980, p. 108-117.

34. _____, 1981, Behavior of Cd, Ni, and Zn in single and mixed combinations in landfill leachates. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 18-28.

35. Garrett, B.C., and others, 1982, Laboratory and field studies of factors in predicting site specific composition of hazardous waste leachate. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 67-86.

36. Glaubinger, Robert S., Kohn, Philip M., and Remirez, Raul, 1979, Love canal aftermath: learning from a tragedy. Chemical Engineering, October 22, 1979, p. 86-92.

37. Green, William J., Lee, G. Fred, Jones, R. Anne, 1981, Clay-soils permeability and hazardous waste storage. Water Pollution Control Federation Journal, Vol. 53, no. 8, p. 1347-1354.

38. Griffin, Robert A., and Chou, Sheng-Fu J., 1980, Disposal and removal of halogenated hydrocarbons in soils. Proceedings - Sixth Annual Research Symposium, Treatment of Hazardous Waste, Chicago, Illinois, March 17-20, 1980, p. 82-92.

39. Gunkel, Robert C., 1981, Membrane liner systems for hazardous waste landfills. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 131-139.

40. Haxo, H.E., Jr., 1981, Durability of liner materials for hazardous waste disposal facilities. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 140-156.

41. Haxo, H.E., Jr., 1982, Effects on liner materials of long-term exposure in waste environments. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 191-211.

42. Helsing, Lyse D., 1981, Affordable technology neutralizes wastes. Waste Age, May, 1981, p. 35-38.

43. Hill, Ronald D., and others, 1981, Four options for hazardous waste disposal. Civil Engineering, September, 1981, p. 82-85.

44. ICF, Inc., 1982. RCRA risk/cost policy model project - Phase 2 Report. US Environmental Protection Agency, Washington, D.C.

45. Illinois Department of Commerce and Community Affairs, 1982. Illinois-state and regional economic data book.

46. Illinois Environmental Protection Agency, 1982, Internal Records (October 5-7 Visit).

47. Illinois Pollution Control Board Public Hearing, February 23, 1982.

48. Josephson, Julian, 1981, Hazardous waste landfills. Environmental Science and Technology, vol. 15, no. 3, p. 250-253.

49. _____, 1982, Immobilization and leachability of hazardous wastes. Environmental Science and Technology, vol. 16, no. 4, p. 219A-223A.

50. Lederman, Peter B., and LaGrega, Michael D., 1981, Managing hazardous wastes. Industrial Wastes, September/October, 1981, p. 36-39.

51. Lenz, Mike, 1982, Lenz Oil, private communication (November 22).

52. Little, A.S., 1979. Draft economic impact analysis, subtitle C, Resource Conservation and Recovery Act of 1976. US Environmental Protection Agency, Washington, D.C.

53. Lubowitz, H.R., and Wiles, C.C., 1981, Management of hazardous wastes by unique encapsulation processes. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p.91-102.

54. McGrena, Richard, 1982, Fisher-Colo, private communication (November 23).

55. Malone, Philip G., and others, 1981, Estimation of pollution potential of industrial waste from small-scale-column leaching studies. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 103-118.

56. Maugh, T., 1982. Just how hazardous are dumps? Science, Vol. 25, January 29, 1982.

57. Maugh, Thomas H., II, 1979, Burial is last resort for hazardous wastes. Science, vol. 204, June 22, 1979, p. 1295-1298.

58. _____, 1979, Incineration, deep wells gain new importance. Science, vol. 204, June 15, 1979, p. 1188-1190.

59. McCoy, Jack, 1982, Trade Waste Incinerator, private communications (November 23).

60. Miller, Richard A., Fox, Robert D., and Pitts, David M., 1981, Evaluation of catalyzed wet oxidation for treating hazardous waste. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 272-276.

61. Mitacek, Michael, 1982, Alburn Incinerator, private comunications (November 18).

62. Modell, Michael, 1981, Processing methods for the oxidation of organics in supercritical water. UK Patent Application No. 8113269, April 29, 1981.

63. Modell, Michael, and others, undated, Destruction of hazardous waste using supercritical water. MODAR, Inc., Natick, Massachusetts.

64. Moore, Charles A., and Ali, Elfatih M., 1982, Permeability of cracked clay liners. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 174-178.

65. Murphy, Hap, 1982, McKesson Envirosystems Co., private communications (November 23).

66. Nagel, Edmond, 1982. McKesson Chemical Company, private communication (November 23).

67. Nevechtel, Michael, 1982, Illinois Environmental Protection Agency, private communications (October 25, November 3, November 23).

68. Oppelt, E. Timothy, 1981, Thermal destruction options for controlling hazardous wastes. Civil Engineering, September 1981, p. 72-75.

69. Pacey, John, and Karpinski, Gail, 1980, Selecting a landfill liner. Waste Age, July, 1980, p. 26-29.

70. Phillips, Jim, 1982, Goldshield Solvents, private communication (November 22).

71. Piet, Bob, 1982, BFI of Illinois, Inc., private communication (November 22).

72. Rose, Clark, 1982, SCA Chemical Services, private communications (November 29).

73. SCS Engineers, 1981. Cost comparisons of treatment and disposal alternatives for hazardous materials, Volumes I and II. US Environmental Protection Agency, Municipal Environmental Research, Cincinnati, OH.

74. Serper, Allen, 1980, Incineration may be best disposal method for most hazardous wastes. Solid Wastes Management, vol. 23, no. 4, p. 122-24, 130-32.

75. Shanoff, Barry S., 1979, Three chemical waste firms come under attack in Illinois. Solid Wastes Management, vol. 22, no. 7, p. 67,87.

76. Shultz, David W., and Miklas, Michael P., Jr., 1980, Assessment of liner installation procedures. Proceedings - Sixth Annual Research Symposium, Treatment of Hazardous Waste, Chicago, Illinois, March 17-20, 1980, p. 135-159.

77. _____, 1981, Installation practices for liners. Proceedings - Seventh Annual Research Symposium, Land Disposal: Hazardous Waste, Philadelphia, Pennsylvania, March 16-18, 1981, p. 157-167.

78. _____, 1982, Procedures for installing liner systems. Proceedings - Eighth Annual Research Symposium, Land Disposal of Hazardous Waste, Ft. Mitchell, Kentucky, March 8-10, 1982, p. 224-238.

79. Sittig, M., 1981, Handbook of toxic and hazardous chemicals. Noyes Publications, Park Ridge, NJ.

80. Sneyd, Robert J., and Mayrose, Dale T., 1980, Fluid-bed incineration. Water and Sewage Works, September, 1980, p. 38-45.

81. Sweet, Wileen E., and McCoy, Andrew J., 1982, Coincineration of high and low BTU wastes. American Institute of Chemical Engineers, Summer National Meeting, Cleveland, Ohio, August, 1982.

82. Taylor, G.C., 1981. Socioeconomic analysis of hazardous waste management alternatives - methodology and demonstration. US Environmental Protection Agency, Municipal Environmental Research, Cincinnati, OH.

83. Tierney, D.R., and Hughes, T.W., 1978, Source assessment: reclaiming of waste solvents, state of the art. Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, EPA-600/2-78-004f.

84. Toxic Substances Strategy Committee, 1980. Toxic chemicals and public protection - a report to the President. US Government Printing Office, Washington, D.C.

85. Toxic Waste Assessment Group, 1981. Alternatives to the land disposal of hazardous wastes - an assessment for California. Governor's Office of Appropriate Technology, Sacramento, CA.

86. US Department of Commerce, Bureau of Economic Analysis, 1977. Industry Specific gross output multipliers for BEA economic areas. US Government Printing Office, Washington, D.C.

87. US Department of Commerce, Bureau of Industrial Economics, 1982. US Industrial Outlook. US Government Printing Office, Washington, D.C.

88. US Environmental Protection Agency, 1976. Assessment of industrial waste practices: paint and allied products industry, contract solvent reclaiming operations, and factory applications of coating. US Government Printing Office, Washington, D.C.

89. US Environmental Protection Agency, 1981. Assessment of emerging technologies for metal finishing pollution control: three case studies. US Government Printing Office, Washington, D.C.

90. US Environmental Protection Agency, 1980. Economic impacts of RCRA approaches to the regulation of generators of small volumes of hazardous wastes. US Government Printing Office, Washington, D.C.

91. U.S. Environmental Protection Agency, 1980, Background document, Resource Conservation and Recovery Act, Subtitle C, Identification and listing of hazardous wastes, sections 1941.28 and 1942.29. May 2, 1980.

92. _____, 1982, List of RCRA Notifiers in Illinois handling listed wastes F001 and F002, September 10, 1982.

93. U.S. Environmental Protection Agency, 1980, Cost Comparison of treatment and disposal alternatives for hazardous wastes, Volumes I and II, SCS Engineers, Inc., Redmond, Washington. December.

94. US Office of Management and Budget, 1976. Standard Industrial Classification Manual. US Government Printing Office, Washington, D.C.

95. Valentine, Ralph S., 1981, LARC - light activated reduction of chemicals. Pollution Engineering, vol. 13, no. 2, p. 35-37.

96. Walzenski, Stan, 1982, Waste Management Inc., private communications (November 22).

97. Ward, JoAnne E., and Ting, Andrew P., 1982, Waste incineration and heat recovery. Environmental Progress, vol. 1, no. 1, p. 30-41.

98. Worthy, Ward, 1982, Hazardous waste: treatment technology grows. Chemical and Engineering News, March 8, 1982, p. 10-16.

99. Wroniewicz, V.S., and Balentine, J.W., 1981, Advanced technology for incinerating hazardous organic wastes. Water Pollution Control Federation, National conference, Detroit, Michigan, October, 1981.

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is study presents an evaluation of the costs and benefits of proposed regulation R81-25 ich would ban the landfilling of chlorinated solvents in Illinois. The disposal of lorinated solvents is authorized (by permit) at six Illinois landfills. Alternatives landfilling include: incineration; solvent reclamation; wet oxidation; coincineration; percritical water reformulation; deep well injection; and solidification/encapsulation. those alternatives, only incineration and solvent reclamation facilities are operational Illinois. If R81-25 is adopted, it is estimated that 80% of the solvents would be cinerated and 20% would be reclaimed. The primary cost of the regulation will be ditional disposal costs: $1.21/gallon to $2.80/gallon. The primary benefits including e following: a decrease in exposure of the population around landfills; reduced tential for potable water supply contamination; an increase in the serviceable life landfills; a decrease in liability incurred by generators and landfill operators; and increase in revenues of firms providing disposal alternatives.

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